EFFECTS OF ANIMAL FEEDING OPERATIONS ON WATER RESOURCES AND THE ENVIRONMENT--

Proceedings of the technical meeting, Fort Collins, Colorado, August 30 – September 1, 1999

U.S. Geological Survey
Open-File Report 00-204

U.S. Department of the Interior
U.S. Geological Survey

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **2000**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Effects of Animal Feeding Operations on Water Resources and the Environment**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Department of the Interior 1849 C Street, NW Washington, DC 20240**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**113**	

Cover: Aerial view of poultry barns at a confined animal feeding operation.
Photograph by Daniel J. Hippe, U.S. Geological Survey.

EFFECTS OF ANIMAL FEEDING OPERATIONS ON WATER RESOURCES AND THE ENVIRONMENT--

Proceedings of the technical meeting, Fort Collins, Colorado, August 30 – September 1, 1999

Franceska D. Wilde, Linda J. Britton, Cherie V. Miller, and
Dana W. Kolpin, Compilers

U.S. Geological Survey
Open-File Report 00-204

Reston, Virginia
2000

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information write to:

Chief, Office of Water Quality
U.S. Geological Survey
12201 Sunrise Valley Drive, MS 412
Reston, VA 20192

Copies of this report can be purchased from:

U.S. Geological Survey
Information Services
Box 25286, Federal Center
Denver, CO 80225

The U.S. Geological Survey's Animal Feeding Operations Web site address is: http://water.usgs.gov/owq/AFO/.

CONTENTS

Effects of Animal Feeding Operations on Water Resources and the Environment--Proceedings of the technical meeting, Fort Collins, Colorado, August 30 – September 1, 1999

By Franceska D. Wilde, Linda J. Britton, Cherie V. Miller, and Dana W. Kolpin, Compilers

INTRODUCTION

The evolution of animal agriculture to meet the needs of a rapidly growing world population is evidenced by a consistent trend toward the replacement of small-to-midsize animal farms with large, industrial-scale animal feeding operations (AFOs) that maximize the number of livestock confined per acre of land. Confinement of large numbers of animals in such operations can result in large loadings of animal feed- and waste-related substances (animal residuals) to the environment. The consequences of waste-management practices at AFOs on ecosystem viability and human health are poorly understood. Potential effects of AFOs on the quality of surface water, ground water, and air, and the implications of such effects on human health pose issues of national concern that require science-based assessment and response.

As part of the 1999 Unified National Strategy for Animal Feeding developed under mandate of the Clean Water Action Plan, the U.S. Department of Agriculture and the U.S. Environmental Protection Agency, together with other Federal partners, were directed to "establish coordinated research, technical innovation, and technology transfer activities…." On August 30 – September 1, 1999, the U.S. Geological Survey (USGS) initiated a meeting of scientists, resource managers, animal producers, and environmental advocates to share information on current research and examine the complex issues related to effects of AFOs on water resources, the environment, and human health. There was consensus at the outset regarding the need for impartial examination of AFO issues, applying multidiscipline and science-based methods of research, monitoring, analysis, and quality control. Participants discussed and identified partnerships among governmental agencies and private organizations as part of a commitment to address these issues in a comprehensive and scientifically defensible manner.

Present at this technical meeting were approximately 200 participants representing the following Federal and State agencies, universities, and private organizations.

Federal agencies

- Bureau of Reclamation
- National Institutes of Health
    - National Institute of Environmental Health Sciences
- National Park Service
- U.S. Department of Agriculture
    - Agricultural Research Service
    - Animal and Plant Health Inspection Service
    - Cooperative State Research, Education, and Extension Service
    - Food Safety and Inspection Service
    - Natural Resources Conservation Service
- U.S. Environmental Protection Agency
- U.S. Fish and Wildlife Service
- U.S. Food and Drug Administration
    - Center for Veterinary Medicine
    - Centers for Disease Control and Prevention
- U.S. Geological Survey

State agencies

Arkansas	Department of Environmental Quality
Colorado	Department of Agriculture
	Department of Public Health and the Environment
California	Department of Water Resources
	Orange Country Water District
Iowa	Department of Natural Resources
Michigan	Department of Agriculture
Minnesota	Environmental Quality Board
Missouri	Department of Agriculture
North Carolina	Division of Water Quality
Nebraska	Department of Environmental Quality
New Mexico	Department of the Environment
Oklahoma	Department of Environmental Quality
Oregon	Department of Agriculture and Natural Resources
Texas	Natural Resource Conservation Commission
Virginia	Department of Agriculture and Consumer Services
Wisconsin	Department of Natural Resources

Universities

- Colorado State University at Fort Collins
- Colorado State University at Sterling
- Colorado State University at Yuma
- George Mason University (Virginia)
- Kansas State University
- North Dakota State University
- Ohio State University
- Oregon State University
- Strom Thurmond Institute, Clemson University (South Carolina)
- Texas A&M University
- University of Arizona
- University of Delaware
- University of Georgia
- University of Iowa
- University of Maryland

University of Minnesota
University of North Carolina, Wilmington
University of North Carolina, Chapel Hill
University of Washington
Yale University (Connecticut)

Private organizations

Environmental Defense Fund
Glorieta Geoscience, Inc.
Hitch Enterprises
Izaak Walton League
Kerr Center for Sustainable Agriculture
Lower Colorado River Authority
National Association of State Departments of Agriculture (NASDA)
Natural Resources Defense Council
Pfizer Animal Health Central Research
Sierra Club
Stroud Water Research Center

Peer Review Process

The usual standards for peer review of abstracts published by the U.S. Geological Survey have been modified to accommodate the variety of styles and review policies used by the participants in this meeting. All abstracts in this report by USGS authors have undergone the review procedures mandated as part of the policy of the USGS and have received Director's approval for publication.

In addition to peer review, the abstracts published in this report have undergone editorial review and have been modified, as needed, to ensure consistent formatting and to correct grammatical errors. Electronic and paper publication of the abstracts or other attachments contained in this document, along with author names and affiliations, is with the approval of the respective author(s).

Acknowledgments

The coordinators of the 1999-Fort Collins AFO technical meeting wish to thank the many people who contributed to the success of this meeting.

The field trip was one of the highlights of the meeting, due in large part to the hospitality, professionalism, and comprehensive overview provided by Mr. and Mrs. Terrance Dye of DyeCrest Dairy and to Frank Haywood, Gerald Vannest, and the staff at National Hog Farms. Special thanks go to Reagan Waskom and Jessica Davis of Colorado State University for helping to identify speakers and for brainstorming with us about the field trip.

Appreciation goes to Judith Griffin (for handling communications and logistical arrangements for the entire meeting); Linda Britton and Neville Gaggiani (for developing and organizing the field trip); Jessica Davis, Reagan Waskom, Kevin Dennehy, and Robert Kimbrough (for providing an overview of AFO practices and effects during the

field trip); William Andrews, Gary Barton, Linda Britton, Herbert Buxton, Rod DeWeese, Sheridan Haack, Michael Meyer, Cherie Miller, and James Preacher (for their assistance in developing the technical structure and content of the meeting); Howard Perlman and Iris Collies (for developing and maintaining the web site); M. Elizabeth Daniel (for her support of the open-session forum); Kimberley Martz (for preparing name tags); Patricia Greene (for design and preparation of signs and posters); Toni Johnson and Toni Koritnik (for assistance with meeting registration and on-site needs); Michele Banowetz (for advice on outreach activities); Judith Salvo and Diane Welch (for shipping and logistical support); Violetta Zaman, Nana Snow, Meredith Tatum, Kizzy Penn, and Deborah Polen (for copying, collating, and compiling over 200 workbooks); and Cindy Furbush (for computer support).

We would like to express appreciation to all meeting presenters and attendees for the high-quality content of their participation. Special acknowledgment is due the USGS Office of Water Quality and Toxic Substances Hydrology Program for co-sponsorship of the 1999-Fort Collins technical meeting to address issues related to AFOs and emerging contaminants, and to the USGS National Water-Quality Assessment Program for its support of this effort.

AGENDA

FIELD TRIP

Monday, August 30, 1999
Field Trip Leaders: Linda J. Britton and Neville G. Gaggiani, U.S. Geological Survey
Field Trip Commentators: Jessica Davis and Reagan M. Waskom, Colorado State University, and Kevin F. Dennehy and Robert A. Kimbrough, U.S. Geological Survey

DyeCrest Dairy - *Fort Collins, Colorado*

National Hog Farms - *Kersey, Colorado*

KEYNOTE SESSION: Perspectives on the Research Needs of Animal Feeding Operations (AFOs)

Tuesday, August 31, 1999
Moderator: Dana W. Kolpin, U.S. Geological Survey

Welcome and opening remarks
Douglas R. Posson – U.S. Geological Survey, Regional Director, Central Region

Science in support of addressing national concerns of environmental and human health
Thomas Casadevall – U.S. Geological Survey, Deputy Director

Past, present, and future of animal feeding operations
Don Ament – Commissioner, Colorado Department of Agriculture

Trends, technology, and challenges for large-scale animal agriculture
Paul Hitch – President and CEO, Hitch Enterprises Inc.

States management of AFOs: Balancing economic benefits and environmental responsibilities
Paul W. Johnson – Director, Iowa Department of Natural Resources

USEPA validation of environmental concerns and development and assessment of national regulations
Roberta Parry – Senior Agriculture Policy Analyst, U.S. Environmental Protection Agency

Manure management research in USDA-ARS
Robert Wright – National Program Staff, Agricultural Research Service, U.S. Department of Agriculture

Documented and potential human health issues related to AFOs

Enzo Campagnolo – Epidemiologist, Epidemic Intelligence, U.S. Department of Health and Human Services, Centers for Disease Control and Prevention (CDC)

Concentrated animal feeding operations (CAFOs)

Mary Henry – Chief, Branch of Ecosystem Health, U.S. Fish and Wildlife Service

TOPICAL SESSION - A: Integration of Environmental Policy and Science

Tuesday, August 31, 1999
Moderator: Linda J. Britton – U.S. Geological Survey

The effect of environmental regulation on the U.S. livestock industry

Dooho Park, A. Seidl, and W.M. Fraiser – Colorado State University, Ft. Collins

Integrating physical and human-induced characteristics in the decision-making process

Carol Mladnich and Richard Zirbes – U.S. Geological Survey, Rocky Mountain Mapping Center

Delaware's animal feeding operations strategy: A critical analysis of the goals and measures of success

J. Thomas Sims – Delaware Water Resources Center, University of Delaware

Research overview of the impacts of confined animal feeding operations on aquatic ecosystems

Thomas A. Muir, J.W. Preacher, and L.R. DeWeese – U. S. Geological Survey, Biological Resources

Monitoring the effects of AFOs in watersheds and aquifers

J.Van Brahana – U. S. Geological Survey, Water Resources

TOPICAL SESSION - B: Human Health and Air and Water Quality

Wednesday, September 1, 1999
Moderator: Paul W. Johnson – Director, Iowa Department of Natural Resources

Air quality around animal feeding operations

Jerry L. Hatfield, R.L. Pfeiffer, and J.H. Prueger – U.S. Department of Agriculture, Agricultural Research Service, National Soil Tilth Laboratory

Environmental and public health risks associated with industrial swine production

Amy R. Chapin and C.M. Boulind – Kerr Center for Sustainable Agriculture

Reduction of odor gases from cattle manure with chemical additives

V.H. Varel and D.N. Miller – U.S. Department of Agriculture, Agricultural Research Service, U.S. Meat Animal Research Center

Determination of the potential toxicity of contaminants in water requires improving the understanding of low-concentration effects

Gary A. Boorman, S.H. Wilson, and R.C. Sills – National Institute of Environmental Health Sciences/Environmental Toxicology Program

TOPICAL SESSION - C: Pathogens

Wednesday, September 1, 1999
Moderator: Sheridan K. Haack – U.S. Geological Survey

Salmonella and other enterobacteriaceae in dairy cow feed ingredients and their antimicrobial resistance

Riam S. Kidd, A.M. Rossignol, M.J. Gamroth, and N.J. Corristan – Oregon State University/Department of Public Health

Swine hepatitis E virus contamination in hog operation waste streams: An emerging infection?

Yuory V. Karetnyi, N. Moyer, Mary J.R. Gilchrist, and Stanley J. Naides – University of Iowa

A system to describe antimicrobial resistance among human and animal populations

David A. Dargatz, P.J. Fedorka-Cray, K.E. Petersen, L. Tollefson, N.E. Wineland, K. Hollinger, and M. Headrick – USDA/APHIS Centers for Epidemiology and Animal Health

Microbial sources tracking

Mansour Samadpour – University of Washington/School of Public Health and Community Medicine/Department of Environmental Health

Investigation of the chemical and microbial constituents of ground and surface water proximal to large-scale swine operations

Enzo Campagnolo, R.W. Currier, M.T. Meyer, D.W. Kolpin, K. Thu, E. Esteban, and Carol Rubin – U.S. Department of Health and Human Services/Centers for Disease Control and Prevention (CDC)

Identification of sources of fecal coliform bacteria and nutrient contamination in the Shoal Creek Basin, southwestern Missouri

John G. Schumacher and J.L. Imes – U.S. Geological Survey, Water Resources

TOPICAL SESSION - D: Pharmaceuticals

Wednesday, September 1, 1999
Moderator: Edward T. Furlong – U.S. Geological Survey

Environmental considerations for animal pharmaceuticals

Charles E. Eirkson III – U.S. Food and Drug Administration, Center for Veterinary Medicine

Occurrence of antibiotics in liquid waste at confined animal feeding operations and in surface and ground water

Michael T. Meyer, J.E. Bumgarner, J.V. Daughtridge, D.W. Kolpin, E.M. Thurman, and K.A. Hostetler – U .S. Geological Survey, Water Resources

Pharm-chemical contamination: A reconnaissance for antibiotics in Iowa streams, 1999

Dana W. Kolpin, D. Riley, M.T. Meyer, P. Weyer, and E.M. Thurman – U .S. Geological Survey, Water Resources

Analysis of tetracycline and sulfamethazine antibiotics in ground water and animal-feedlot wastewater by high-performance liquid chromatography/mass spectrometry using positive-ion electrospray

E. Michael Thurman – U .S. Geological Survey, Water Resources

A reconnaissance for hormone compounds in the surface waters of the U.S.A.

Larry B. Barber, G.K. Brown, D.W. Kolpin, and S.D. Zaugg – U .S. Geological Survey, Water Resources, National Research Program

TOPICAL SESSION - E: Nutrients

Wednesday, September 1, 1999
Moderator: Cherie V. Miller – U.S. Geological Survey

Hydrogeologic settings of earthen waste storage structures associated with CAFOs in Iowa

Michael R. Burkart and W.W. Simpkins – U.S. Department of Agriculture, Agricultural Research Service

Nutrients available from livestock manure relative to land use

David C. Moffitt and C.H. Lander – U.S. Department of Agriculture, Natural Resources Conservation Service

Predicting surface water impacts from concentrated animal feeding operations: A national analysis using the SPARROW model

Kathy Zirbser – U.S. Environmental Protection Agency

TOPICAL SESSION - E: Nutrients, continued

Phosphorus geochemistry in two coastal plain watersheds with different land-management practices: Processes involving organophosphorus compounds

Nancy S. Simon, J. Isbister, and J. Margraf – U.S. Geological Survey, Water Resources, National Research Program

Nutrient imports to support AFOs in the Black River Basin, NC

Lawrence B. Cahoon and M.A. Mallin – University of North Carolina, Department of Biological Sciences

Interaction between surface and ground water in the transport of nutrients from animal wastes in karst terrain

Thomas J. Sauer – U. S. Department of Agriculture, Agricultural Research Service; J.V. Brahana, U.S. Geological Survey; T.M. Kresse, Arkansas Department of Environmental Quality

Field evaluation of animal-waste lagoons: Seepage rates and subsurface nitrogen transport

Jay M. Ham – Kansas State University, Department of Agronomy

Treating livestock manure: Available technology, effectiveness, and costs

Jose R. Bicudo and J. Zhu – University of Minnesota, Department of Biosystems and Agricultural Engineering

FORUM SESSION: Open Exchange Among Participants

Wednesday, September 1, 1999
Moderator: L. Rod DeWeese – U.S. Geological Survey
Facilitator: M. Elizabeth Daniel – U.S. Geological Survey

The meeting was opened to all attendees for discussion relating five questions:

1. What are the major scientific questions/topics lacking information that could significantly add to the overall understanding of the environmental implications of AFOs?
2. Can you provide examples of successful interagency (State and Federal) and government/private collaborative efforts concerning AFOs?
3. What do you see as inhibiting collaborative efforts on AFOs?
4. What changes or improvements do you recommend to increase collaborative partnerships among government and non-government interests in AFOs?
5. Where do we go from here?

POSTER SESSION

Tuesday, August 31 - Wednesday, September 1

Evaluation of swine effluent as plant nutrient source for sprinkler irrigated corn

Mahdi M. Al-Kaisi and R.M. Waskom – Colorado State University Cooperative Extension

An inquiry into the rationale for prioritizing South Carolina's animal feeding operations for water pollution regulation

J. Allen, K. Shou Lu, and Sean P. Blacklocke – The Strom Thurmond Institute

Time-series sampling for nutrients and bacteria in ground water at four north Florida dairy farms and three springs along the Suwannee River, 1990-93

William J. Andrews – U.S. Geological Survey, Water Resources

Comparison of water-quality in four small watersheds containing animal feeding operations in Iowa, 1996-98

Kent D. Becher and K.K.B. Akers – U.S. Geological Survey, Water Resources

Agriculture and bacterial ground-water quality in Central Appalachian karst

Douglas G. Boyer – U.S. Department of Agriculture, Agricultural Research Service

Preliminary observations on nitrogen speciation and transport in two watersheds of the Chesapeake Bay Estuary

Owen P. Bricker, M.M. Kennedy, and P. Chirico – U.S. Geological Survey, Water Resources, National Research Program

High-performance liquid chromatography/electrospray ionization – mass spectrometry analysis of agricultural and human health pharmaceuticals in surface and ground water

Jeffrey D. Cahill, Edward T. Furlong, S.L. Werner, M.R. Burkhardt, and P.M. Gates – U.S. Geological Survey, National Water Quality Laboratory

Odors, nuisance, and the right to farm

Terence Centner – University of Georgia

Ground-water quality at 94 dairies in New Mexico

Claybourne Chesney – U.S. Environmental Protection Agency, Region 6

Distribution and fate of nitrate in shallow ground water of citrus farming areas, Indian River, Martin, and St. Lucie Counties, Florida

Christy A. Crandall – U.S. Geological Survey, Water Resources

Impacts of animal feeding operations on wildlife health
Lynn H. Creekmore, M.J. Wolcott, and M.D. Samuel – U.S. Geological Survey, Biological Resources, National Wildlife Health Center

Ground-water protection and manure management
Matthew Culp – Iowa Geological Survey Bureau

Microbiological quality of public-water supplies in the Ozark Plateaus aquifer system, Missouri
Jerri Davis – U.S. Geological Survey, Water Resources

A risk-based approach to phosphorus management on manured and non-manured soils
Jessica Davis – Colorado State University

Nitrogen, sulfate, chloride, and manganese in ground water in the alluvial deposits of the South Platte River Valley near Greeley, Weld County, Colorado
Neville G. Gaggiani – U.S. Geological Survey, Water Resources

Abundance, dissemination and diversity of Escherichia coli in a watershed in northern Michigan, USA
Sheridan K. Haack, J.S. Wilson, S.M. Woodhams, D.T. Long, B.C. Pijanowski, D.F. Boutt, and D.W. Hyndman – U.S. Geological Survey, Water Resources

Use of a hydrogeologic framework to examine the effects of agricultural fertilizers and manure applications of nutrients in shallow ground water of the Mid-Atlantic Coastal Plain
Tracy C. Hancock, S.W. Ator, S.K. Kelley, and J.M. Denver – U.S. Geological Survey, Water Resources

Potential exposure of the nation's waters to animal manure
Kerie J. Hitt, B.C. Ruddy, and J.D. Stoner – U.S. Geological Survey, Water Resources

Regulating intensive livestock operations in North Carolina
Sue Homewood – North Carolina Department of Environment and Natural Resources

Concentrations and microbial impact of environmental antibiotics in a watershed affected by local land-management practices as compared to a reference watershed
Thomas B. Huff, J. Isbister, N.S. Simon, and T. Tu – George Mason University

National Association of State Departments of Agriculture CAFO survey results
Charles W. Ingram and Jeffrey G. Anliker – National Association of State Departments of Agriculture

Development of comprehensive management plans for animal feeding operations
Thomas A. Iivari – U.S. Department of Agriculture, Natural Resource Conservation Service

Hepatitis E virus antibody prevalence among selected populations in Iowa
Youry V. Karetnyi, M.J.R. Gilchrist, and Stanley J. Naides – University Hygienic Laboratory, University of Iowa

A multi-tracer approach for determining sources of nitrate contamination of ground water and springs, Lafayette County, Florida
Brian G. Katz, J.K. Bohlke, and D.H. Hornsby – U.S. Geological Survey, Water Resources

Integrated approach for a comprehensive nutrient management plan at Pahrump Dairy, Nevada
Jay Lazarus, C.D. Ratcliff, and E. Goedhart – Glorieta Geoscience, Inc.

Methods of assessing microbial contamination of surface and ground waters by animal feeding operations
Donna N. Myers – U.S. Geological Survey, Water Resources

Dairy impacts to water quality and Orange County Water District's comprehensive dairy waste management strategy
Katherine A. O'Connor – Orange County Water District, San Diego Calif.

Quantity and quality of seepage from two earthen basins used to store livestock waste during first year of operation in southern Minnesota, 1997-98
James F. Ruhl – U.S. Geological Survey, Water Resources

The shaping of law through ten years of hog production in Oklahoma
Karl M. Rysted – The Sierra Club

Minnesota's generic environmental impact statement on animal agriculture
Susan Schmidt – State of Minnesota, Environmental Quality Board

Contaminants and related effects in fish from the Mississippi, Columbia, and Rio Grande Basins

Christopher J. Schmitt, T.M. Bartish, Vicki S. Blazer, D.E. Tillitt, T.S. Gross, G. Dethloff, N.D. Denslow, W.L. Bryant, and L.R. DeWeese – U.S. Geological Survey, Biological Resources

Phosphate sorption by base metal hydroxides generated in the neutralization of acid mine drainage

Phillip L. Sibrell and P. Adler – U.S. Geological Survey, Biological Resources

Delaware's animal agriculture: Its role in nonpoint source pollution and options for the future

J. Thomas Sims – Delaware Water Resources Center, University of Delaware

Identification of sources of nitrate in ground water: A feasibility evaluation

Timothy B. Spruill – U.S. Geological Survey, Water Resources

Molecular tracers of organic matter sources to drinking water supplies

Laurel J. Standley, L.A. Kaplan, and D. Smith – Stroud Water Research Center

Cycling of sulfur in the Anoka sand plain aquifer and its relation to denitrification

Michele L. Tuttle, J.K. Bohlke, Richard Wanty, G.N. Delin, and M.K. Landon – U.S. Geological Survey, Geology

Roxarsone in natural water systems

Robert L. Wershaw, J.R. Garbarino, and M.R. Burkhardt – U.S. Geological Survey, Water Resources, National Research Program

Nitrous oxide emission from a spray field fertilized with liquid lagoonal swine effluent in the southeastern United States

Stephen C. Whalen, R.L. Phillips, and E.N. Fischer – University of North Carolina

Evaluating the cumulative impacts from animal feeding operations within impaired watersheds in Texas: A regulatory approach

Clifton F. Wise – Texas Natural Resource Conservation Commission

ABSTRACTS

Keynote Session: Perspectives on the Research Needs of Animal Feeding Operations (AFOs)

The views and conclusions contained in this document from authors not affiliated with the U.S. Geological Survey are solely those of the authors and should not be interpreted as necessarily representing the views or official policies, either expressed or implied, of the U.S. Geological Survey.

Science in Support of Addressing National Concerns of Environmental and Human Health

Thomas Casadevall[1]

In recent months, the news media have reported increasing concerns about the effects that a growing number of concentrated animal feeding operations (AFOs) might have on water resources and the environment. Concerns include the possible release to the hydrologic cycle of an excessive volume of nutrients and the introduction of antibiotics used in animal husbandry. The U.S. Geological Survey (USGS), as a leading science agency within the Department of the Interior, has responsibility to provide Federal and State management and regulatory agencies with reliable and comprehensive scientific information needed for assessing the extent to which human and environmental health might be at risk. The USGS has convened this meeting to (1) provide a forum in which scientists, managers, and producers can share information and form partnerships to address AFO issues; and (2) listen and respond better to the needs of other agencies and organizations.

Integrated science and professional partnerships with university and government researchers and resource managers are part of the key to the resolution of complex environmental issues. Having a nationally distributed, multidisciplinary workforce, the USGS conducts a wide variety of short- and long-term studies, research, and methods development that are field and laboratory based. Scientific expertise is integrated among biologists, hydrologists, geologists, chemists, cartographers, statisticians, mathematicians, computer modelers, and other disciplines to provide the scientific underpinning needed to address global and regional concerns. The development and use of nationally consistent and technically sound protocols and quality-assurance procedures is an emphasis in all studies. Such studies typically are initiated in direct response to requests from local or State agencies, in addition to those developed in partnership with other federal and international agencies. The development and maintenance of long-term national and international databases is a vital component of the USGS program.

---

[1]U.S. Geological Survey, MS 100, 12201 Sunrise Valley Drive, Reston, VA 20192 (tcasadev@usgs.gov)

The Past, Present, and Future of Animal Feeding Operations

Don Ament[1]

Animal feeding operations are a relatively new phenomenon in the U.S. agricultural landscape. Its growth in the past 50 years can be attributed to consumer demand for high quality meats at affordable prices. Today, most of this country's meat products were finished to consumer preferences in confined animal feeding facilities. Consequently, much of the country's agricultural sector has evolved to one that serves the feeding industry, such as the production of corn, other feed grains, and hay.

Recently, the animal feeding industry has come under attack by those who perceive it to be a major source of water or air pollution. Other critics of animal feeding operations include those who perceive them to be cruel and inhumane to animals or who are concerned over a perceived change in the structure of American agriculture. Regardless, critics are often less than fully informed as to the true nature of the operations, including environmental aspects.

It is critical that America's environmental policy address the relevant issues involved from the standpoint of proper and appropriate scientific analysis. To manage these issues from the standpoint of perception is to cause unnecessary disruption throughout much of the Nation's agricultural system.

[1]Commissioner, Colorado Department of Agriculture, 700 Kipling Street, Suite 4000, Lakewood, CO 80215-5894 (lorna.columbia@ag.state.co.us)

Trends, Technology, and Challenges for Large-Scale Animal Agriculture

Paul H. Hitch[1]

Large-scale animal agriculture has changed dramatically in the last twenty years. It has increased at an impressive (or alarming, depending on your point of view) rate, with concomitant increases in efficiency of production. This increase in efficiency has been accompanied by more uniformity in products, at least in pork and poultry. Beef is still struggling with the problems of an inconsistent product.

In spite of the fact that we in animal agriculture produce uniform, delicious food, all is not happy in the agricultural arena. For one thing, prices are terrible. For another, the public less and less is inclined to view us as protectors of our natural resources, and more and more view us as polluters or as potential polluters. So, we need some help. Here are some modest proposals:

<u>Odor</u> – The hot button issue with pork production is odor. Please research the products and/or management techniques that will reduce the odor from pork production.

<u>Sludge</u> – Cattle feedlots have retention ponds in which sludge accumulates. These ponds are, in many instances, not designed to operate as anaerobic digestors. The sludge simply accumulates over the years. Any research on mechanical/biological sludge reduction would be of immense benefit to cattle feeders.

<u>Dust</u> – Dust is a problem of differing but recurring intensity to cattle feeders. What is the cost in terms of animal performance? What is the effect on employee health? And what can be done to reduce the dust from feedyard pens?

<u>Lagoon Seepage</u> – All clay lined lagoons seep. What happens to that seepage rate over time? Does it increase or decrease? What happens to the nutrients in the lagoon water as it seeps through the liner? Are they caught up in the soil and held there?

<u>River Contamination</u> – All agriculture is being held liable for excess nutrients in our Nation's rivers and streams. I'd like to know what the nutrients are and where they came from. Some possible sources are: Golf courses, municipal sewage plants, urban lawns, crop farming, animal agriculture, natural decomposition of vegetative matter, and septic systems. There may be others. We desperately need research to determine the source of the nutrients and the conditions that lead to their arrival in the river (excess rainfall, excess rainfall following drought, winter, summer, etc.) You cannot fix a problem until you know what the problem is. My concern is that agriculture, in general, and animal agriculture, in particular, is being blamed for excess nutrients in the rivers and streams. I don't believe the science exists to justify this position. I'd like to see the science done.

<u>Antibiotic-resistant bacteria</u> – There are a number of people who believe that the use of antibiotics in animal agriculture is contributing to the problems of resistant bacteria in humans. So far as I know, no scientific study has proven that this is the case. Unfortunately, no study has disproven it either. We need some science done in the area of antibiotic use in animal production and it's effect on human health. In the absence of facts, emotions drive decisions. This is not good.

<u>Efficiency of effluent application</u> – Some States are considering mandating that effluent be knifed into the soil, with the supposition that this is more environmentally friendly. There may be some odor reduction in this application, but I don't believe it has been quantified. How do you balance that against the costs (and pollution) of running the tractor to incorporate the effluent into the soil? How does that compare to applications through a center pivot sprinkler in terms of energy used? These questions need answers. Inquiring minds want to know!

I'm sure I have not exhausted the list of things that we in animal agriculture need to know more about. I've tried to stick to those topics that have impacts on environmental or human health. When you have completed these assignments, contact me and I'll have more.

---

[1]Hitch Enterprises, P.O. Box 1308, Guymon, OK 73942-2735 (phitch@hitchok.com)

States' Management of AFOs: Balancing Economic Benefits and Environmental Responsibilities

Paul Johnson[1]

We often hear the dual challenge "common sense and good science." Unfortunately, we are now faced with an animal agriculture that seems to have ignored both. Bringing sense and reason to our present condition will demand agreement on basic standards, followed by challenging scientific and technical innovations. It will also call us to individual and corporate responsibility that many have thus far been unwilling to accept.

---

[1]Director, Iowa Department of Natural Resources, Wallace State Office Building, 502 E. 9th Street, Des Moines, IA 50319-0034 (jgookin@max.state.ia.us)

U.S. Environmental Protection Agency Validation of Environmental Concerns and Development and Assessment of National Regulations

Roberta Parry[1]

The U.S. Environmental Protection Agency (EPA) recognizes that animal feeding operations (AFOs) pose a variety of threats to human health and the environment. Pollutants from livestock operations include: nutrients, organic matter, sediments, pathogens, heavy metals, hormones, antibiotics, dust, and ammonia. In response to increasing awareness of the pollution threats and changes in the livestock industry, EPA is developing a series of water-quality regulations and guidance that will impact AFOs directly and indirectly. The focus of these actions is on the control of nutrient leaching and runoff .

Concentrated Animal Feeding Operations (CAFOs) are defined as point sources under the Clean Water Act, and therefore, are required to obtain a permit to discharge to waters of the United States. The existing CAFO regulations, which are over 20 years old, are being revised. Three new CAFO regulations will be proposed in December 2000--effluent guidelines for pork and poultry, effluent guidelines for beef and dairy, and permitting regulations. Effluent guidelines establish the best available technology economically achievable for CAFOs over a certain size threshold. The permitting regulations address smaller CAFOs and describe additional requirements such as monitoring and reporting.

The U.S. Department of Agriculture (USDA) and EPA National Unified Animal Feeding Operation Strategy, released in March 1999, established a national goal for all 450,000 AFO owners and operators to develop and implement a Comprehensive Nutrient Management Plan (CNMP). A CNMP includes: feed management, manure handling and storage, land application of manure, site management (e.g., tillage, riparian buffers), record keeping, and other utilization options where an inadequate land base is available to properly apply the manure. CNMPs would be required for the approximately 15,000 to 20,000 CAFOs covered by Clean Water Act regulations. The other AFOs would implement CNMPs voluntarily with cost-share and technical assistance under a variety of Federal and State programs.

EPA's Draft Guidance Manual and Example National Pollutant Discharge Elimination System (NPDES) Permit for CAFOs, released in August 1999, interprets existing CAFO regulations. It clearly states the requirement of CAFOs to obtain a permit, which includes a CNMP. Corporations that exert substantial operational control over CAFOs also will be permitted.

The proposed Total Maximum Daily Load (TMDL) regulations and the development of nutrient water-quality criteria will impact AFOs indirectly. The nutrient criteria will be used by the States to establish quantitative standards for nitrogen and phosphorus in all water bodies. Currently, most nutrient standards are qualitative.

States are required to develop TMDLs for water bodies that do not meet the standards for nutrients or other pollutants. A TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water-quality standards. Through the TMDL process, pollutant loads will be allocated to all sources. In some impaired watersheds, AFOs may be impacted since improved management practices will be necessary to restore water quality.

---

[1]U.S. Environmental Protection Agency (2121), Ariel Rios Building, 1200 Pennsylvania Ave., NW, Washington, DC 20460 (parry.Roberta@epa.gov)

Manure Management Research in USDA-ARS

Robert J. Wright[1]

Manure generated at 300,000 animal feeding operations (AFOs) can pose a threat to soil, water, and air quality and to human and animal health. Some of the main problems facing AFOs include: nutrient enrichment of soil and water, emission of odors and greenhouse gases, and control of pathogenic microorganisms. The U.S. Department of Agriculture—Agricultural Research Service (USDA-ARS) uses several approaches to address each area including animal feeding, manure handling, storage and treatment methodologies, land-application protocols, conservation practices, decision-support tools, and alternative uses.

Research is needed to make more efficient use of feed by livestock and poultry and to match feed nutrient concentrations to animal requirements. This approach can reduce volume of manure produced, nutrients excreted, and production costs. Progress has been made in reducing nitrogen and phosphorus concentrations in manure through more efficient use of dietary nutrients.

Losses of nutrients from manure occur during handling and storage and during and after field application. Improved manure handling, storage, and treatment technologies; improved tests for nutrients in manure and soil; tools to identify areas in a watershed susceptible to nutrient losses; improved methods for manure application; and agricultural systems to effectively use and recycle nutrients are needed. Manure amendments have reduced ammonia volatilization and phosphorus solubility. Nutrient recovery from wastewater has been enhanced through improved liquid-solid separation and new treatment technologies. The P Index is being developed to identify and rank the vulnerability of sites to phosphorus loss in runoff. Effectiveness and placement of buffer strips, wetlands, and riparian zones for nutrient and pathogen removal are being evaluated.

Three types of emissions (gases, particulates, and aerosols) affect air-quality changes around livestock operations. Ammonia emissions appear to have the greatest potential for adverse environmental and health impacts, while odorous compounds provoke the greatest public concern. Development of cost-effective methods to reduce and control emissions will require a greater understanding of emissions formation, composition, emission rates, and dispersion. Methods have been developed to measure emission rates from animal-housing and manure-storage facilities. Preliminary results suggest that nitrogen gas rather than ammonia is the primary form of nitrogen released from several lagoons in the Southeast.

Pathogens and parasitic agents in manure can be transmitted to other animals and humans through food supplies and water. Bacteria such as *Escherichia coli, Salmonella, Camplyobacter,* and *Listeria,* and the parasite *Crytosporidium parvum,* have been implicated in human illness. Research will be needed to determine survival, transport and dissemination of manure pathogens in the environment, to assess risks, and to develop appropriate control measures. Initial research has focused on survival of manure pathogens under different conditions and treatments.

Alternative uses for manure are needed in areas where supply exceeds available land and where land application would cause significant environmental risk. Manure use for energy production, composting, pelletizing, or transportation subsidies may be required in areas of oversupply. Alternative production systems that emphasize balancing nutrient inputs and outputs on the farm will need to be evaluated and used where appropriate.

---

[1]U.S. Department of Agriculture, Agricultural Research Service, 5601 Sunnyside Avenue, Rm 4-2262, Beltsville, MD 20705-5140 (rjw@ars.usda.gov)

Documented and Potential Human-Health Issues Related to Animal Feeding Operations

Adam Karpati[1], Carol Rubin[2], W. Randolph Daley[3], and Enzo R. Campagnolo[4]

The Centers for Disease Control and Prevention (CDC) is involved in evaluating the impact of concentrated animal feeding operations (CAFOs) and animal waste on public health. Increasing attention is being paid to these issues due to the growth and consolidation of the farming industry. This presentation reviews the human-health issues surrounding animal waste by focusing on specific pathogens, the problem of antibiotic resistance, recent CDC investigations, and implications for animal-waste management. Infectious agents found in animal waste include bacteria, protozoa, and viruses. Toxins associated with animal waste include nitrates and components of aerosols, as well as algal toxins. Sub-therapeutic antibiotic use in livestock has contributed to the development of antibiotic resistance among bacteria with domestic-animal reservoirs. These resistant bacteria pose a threat to human health. CDC has participated in studies of water quality and antimicrobial resistance in bacteria around CAFOs in Ohio and Iowa. Preliminary results indicate the presence of antibiotic-resistant bacteria in some surface-water samples from these sites. Future development of policies on manure management and antibiotic use in animals should include consideration of the public-health implications, with recommendations based on rigorously collected scientific data. Federal and State agencies should work together with academic institutions and industry to set research agendas and conduct scientific studies that address these issues.

---

[1]National Center for Environmental Health, Centers for Disease Control and Prevention, 4770 Buford Highway, N.E., MS: F-46, Atlanta, GA 30341-3724

[2]National Center for Environmental Health, Centers for Disease Control and Prevention, 4770 Buford Highway, N.E., MS: F-46, Atlanta, GA 30341-3724 (chr1@cdc.gov)

[3]National Center for Environmental Health, Centers for Disease Control and Prevention, 4770 Buford Highway, N.E., MS: F-46, Atlanta, GA 30341-3724

[4]National Center for Environmental Health, Centers for Disease Control and Prevention, 4770 Buford Highway, N.E., MS: F-46, Atlanta, GA 30341-3724 (ejc5@cdc.gov)

Concentrated Animal Feeding Operations (CAFOs)

Mary G. Henry[1]

Concentrated Animal Feeding Operations (CAFOs) are agricultural businesses where animals are grown under confined conditions, with many individuals crowded into one facility located on a few acres. Nationwide, the number of CAFOs has increased dramatically within the past several years. Although the number of producers has decreased, the number of animals per unit has increased. CAFOs commonly are clustered in one location or county.

CAFOs produce massive amounts of waste, including manure, urine, excess feed, and dead animals, which must be disposed of daily. This commonly is done by storing the waste in lagoons or holding facilities that frequently overflow as a result of exceeding the holding capacity or because of excessive rainfall. During these events, this untreated waste flows into nearby streams, wetlands, or watersheds. This waste also is spread on fields as fertilizer, which runs off into nearby waterways as nonpoint-source pollution.

Reduced water quality, through nutrient loading causing oxygen depletion and eutrophication, results in algal blooms and fish kills. Animal waste also has been linked to avian botulism and cholera, which are major threats to migratory birds. Other by-products of CAFOs include chemicals, ammonia and hydrogen sulfide gases, hormones, medicines, heavy metals, pesticides, and pathogens. These pollutants threaten the health and survival of wildlife, especially threatened and endangered species, and the land their existence relies on.

Changes need to occur to assure the continued health of our trust resources. More examples are needed to convince the farming industry and regulating agencies to support changes in the management, regulation, and enforcement of laws addressing CAFOs. In order to accomplish this change, we need to document the effects of CAFOs, distribute this information, and invite the industry to participate in creating the solutions. Only by forming partnerships and working as a team will a strategy be formed that all players can endorse and enforce.

---

[1]U.S. Fish and Wildlife Service, Branch of Ecosystems Health, 4401 North Fairfax Drive, Suite 322, Arlington, VA 22203 (henry_mary@fws.gov)

Topical Session A: Integration of Environmental Policy and Science

The Effect of Environmental Regulation on the U.S. Livestock Industry

Park Dooho[1], Andrew Seidl[2], and W. Marshall Fraiser[3]

Since enactment of the 1972 Clean Water Act (CWA), industries potentially creating point sources of water pollution are required to obtain National Pollutant Discharge Elimination System (NPDES) operating permits. With revision of the CWA in the mid-1980s, livestock operations of greater than 1,000 Animal Units, or those found in environmentally sensitive locations, also were subject to regulation. Currently, 43 States have enforcement authority of NPDES permits by the U.S. Environmental Protection Agency. In addition, State and local concerns surrounding environmental management of livestock operations created a mosaic of State-level environmental policy conditions. In 1998, at least a half-dozen States and the Federal Government considered legislation to more closely monitor emissions from livestock operations. Environmental policies applied to livestock generally discriminate against larger, incorporated, or vertically integrated operations. These policies tend to address ground- and surface-water concerns and, increasingly, air-quality issues.

Concurrently, the livestock industry has been in a state of change. Due to technological innovation and lower transportation costs, the livestock industry has become less tied to feed supplies. The choice of where to locate is determined largely by access to input and output markets, technology employed, and the environmental attributes of the land. Lower transportation costs free location decisions and result in the specialization and concentration of several livestock species industries. It has been hypothesized that the stringency of environmental regulation is either (a) driven by or (b) becomes the catalyst for change in the livestock industry. Alternatively, the willingness and ability to enforce regulations may affect location and stocking decisions. Currently, little empirical evidence testing these hypothesized relationships is found in the literature.

This paper examines the state level (50 States) effects of environmental policy across livestock species (for example, hogs, beef cattle, dairy, and chickens) over the almost three decades since the passage of the CWA. We differentiate between the letter of the law and indicators of the willingness to enforce it on a State-by-State basis. State level differences between environmental policies and growth rates are developed by livestock species over time. We expect changes in stocking rates and operation profiles to lag the imposition of new environmental policies for existing operations and anticipate them for new operations. We expect the combination of the stringency of environmental regulation, coupled with the willingness to enforce them (for example, highest average compliance costs), will most strongly guide the evolution of the livestock industry when location factors are most open. Potential information emanating from this study includes the efficacy of uniform Federal standards for reaching national water-quality objectives and evidence about the effectiveness of competition among States for livestock-based economic development using weak environmental policy as an attractor for the industry.

---

[1]Colorado State University, Fort Collins, CO 80523 (dhpark@lamar.colostate.edu)
[2]Colorado State University, Fort Collins, CO 80523 (aseidl@agsci.colostate.edu)
[3]Colorado State University, Fort Collins, CO 80523 (mfraiser@lamar.colostate.edu)

Integrating Physical and Human-Induced Characteristics in the Decision-Making Process

Carol Mladinich[1] *and Richard Zirbes*[2]

Decisions regarding land and resources are complex and emotionally charged. Features on or below the land surface often are not taken into account nor clearly portrayed. By combining the physical characteristics of the land with the human settlement patterns, we can achieve a more accurate and comprehensive depiction of the landscape, which can help communities make decisions regarding growth and its impacts. The U.S. Geological Survey Front Range Infrastructure Resources project is developing a Group Spatial Decision Support System for integrating the scientific data characterizing an area; such integrated information will help people make decisions that can mitigate many of the consequences of growth.

---

[1]U.S. Geological Survey, Box 25046, MS 516, Denver, CO 80225-0046 (csmladinich@usgs.gov)
[2]U.S. Geological Survey, Box 25046, MS 516, Denver, CO 80225-0046 (rjzirbes@usgs.gov)

Delaware's Animal Feeding Operations Strategy: A Critical Analysis of the Goals and Measures of Success

J. Thomas Sims[1]

More than 25 years of research has shown that agricultural nutrients are impacting Delaware's ground and surface waters. Nitrate contamination of ground waters used as drinking-water supplies and eutrophication of fresh and estuarine waters by agricultural nitrogen (N) and phosphorus (P) are the major water-quality problems in Delaware historically, and today. Human-health concerns related to eutrophic waters (for example, *Pfiesteria*) have emerged in recent years and created an additional impetus for improving agricultural nutrient management.

Delaware agriculture is dominated by a large and geographically intense poultry industry. Approximately 260,000,000 broiler chickens are produced each year in a State with about 225,000 hectares (ha) of cropland. Research has shown that the nutrient surpluses and nutrient-management problems associated with concentrated poultry production play a major role in nonpoint-source pollution of Delaware waters by agriculture. Fertilizer N use is another significant factor. In 1997, Delaware entered into a Total Maximum Daily Load (TMDL) agreement with the U.S. Environmental Protection Agency (USEPA) as a result of a lawsuit filed against USEPA by a consortium of environmental groups. In the TMDL agreement, the State of Delaware agreed to reduce N and P loads to surface waters by as much as 60-85%. Close upon the TMDL settlement have come State efforts to develop a coordinated response to the newly developed U.S. Department of Agriculture (USDA)-USEPA Unified Strategy for Animal Feeding Operations. A Governor's Agricultural Industry Advisory Committee on Nutrient Management prepared a series of recommendations in late 1998 and proposed legislation in the spring of 1999 that would establish a Delaware Nutrient Management Commission to "..*regulate those activities involving the generation and application of nutrients in order to help improve and maintain the quality of Delaware's ground and surface waters to meet or exceed federally mandated water quality standards, in the interest of overall public welfare"*. Similar legislation has been passed in Maryland, Pennsylvania, and Virginia.

One of the major needs in the ongoing effort to improve nutrient management for water-quality protection is a systematic process to clearly establish goals and document success. This presentation critically analyzes the establishment of nutrient-management goals that will achieve water-quality improvement and outlines a series of measures that can be used to determine if we are progressing toward these goals. The emphasis will be on the changes needed in nutrient management by animal agriculture, and specific recommendations will be made on the most effective means to implement change, as well as areas where future research should be focused.

---

[1]Delaware Water Resources Center, University of Delaware, Newark, DE 19717-1303 (jtsims@udel.edu)

A Research Overview of the Effects of Confined Animal Feeding Operations on Aquatic Ecosystems

Thomas A. Muir[1], Franceska D. Wilde[2], James W. Preacher[3], and Lawrence R. DeWeese[4]

Confined animal feeding operations are a rapidly growing sector of the United States agricultural economy. The U.S. Geological Survey (USGS) is actively involved in research efforts to assess the effects of Animal Feeding Operations (AFOs) on aquatic ecosystems and on the chemical quality of ground-water and surface-water resources. The purpose of this presentation is to provide an overview of USGS research and monitoring activities related to AFOs. In addition, some USGS capabilities for studying the effects of AFOs on aquatic biota and the effects of aquaculture on the environment will be examined.

USGS scientists are applying diverse and interdisciplinary approaches to ecosystem research, in particular with respect to understanding contaminant transport and assimilation processes. Questions being addressed through research and on-site monitoring involve the occurrence and magnitude of nutrients, pharmaceuticals, and pathogens that could be entering streams and ground-water systems and that originate from concentrated sources of animal feed and waste products. The results of these studies are germane to public concerns that industrial-scale livestock, dairy, swine, poultry, and aquaculture operations could have acute, long-term, and cumulative effects on riparian, surface-water and ground-water resources.

A summary of some of the major categories of USGS research and investigations related to concentrated animal feeding operations follows:

PHARMACEUTICALS (antibiotics and endocrine disruptors): Reconnaissance sampling of 100 streams across the United States is underway to provide baseline data on the occurrence of antibiotics in streams. Occurrences of antibiotics will be compared with predominant animal types for respective watersheds.

PATHOGENS (viruses, bacteria, and protozoa): Streams and ground water adjacent to high-density animal production facilities are being sampled for pathogens in five States.

NUTRIENTS (nitrates, ammonia, phosphorus): Monitoring the water quality of springs in a region of northern Arkansas populated with poultry AFOs is ongoing to determine the nonpoint source of nutrient contamination.

METALS, TRACE ELEMENTS, AND PESTICIDES: The fate and transport of these contaminants in runoff from dairy operations in California is being investigated.

TECHNOLOGY AND METHODS DEVELOPMENT: Analytical methods to detect low concentrations of some of the most prevalent classes of pharmaceutical compounds are being developed and validated. DNA testing is being conducted to determine the source (poultry or cattle) of fecal-coliform contamination in Missouri streams. RNA ribotyping techniques are being developed and applied to track the source of microorganisms in Virginia streams and ground water near AFOs. Age dating and nitrogen isotope ratio analyses are being applied to ground-water samples in Colorado to determine the origin of elevated nitrate and ammonia. Computer models, such as SPARROW, are being developed and adapted to assist water-resource managers in their decision making

---

[1]U.S. Geological Survey, MS 300, 12201 Sunrise Valley Drive, Reston, VA 20192 (tom_muir@usgs.gov)
[2]U.S. Geological Survey, MS 412, 12201 Sunrise Valley Drive, Reston, VA 20192 (fwilde@usgs.gov)
[3]U.S. Geological Survey, MS 300, 12201 Sunrise Valley Drive, Reston, VA 20192 (jim_preacher@usgs.gov)
[4]U.S. Geological Survey, P.O. Box 25046, MS 406, DFC, Denver, CO 80225-0046 (rdeweese@usgs.gov)

Hydrologic Monitoring to Characterize Dominant Controls of Ground-Water Flow and Transport in an Area of Confined Animal Operations on a Mantled Karst Terrane, Northwestern Arkansas

J. Van Brahana[1], Thomas J. Sauer[2], Phil Hays[3], Timothy M. Kresse[4], Paul Little[5], and Jaysson Funkhouser[6]

The Savoy Experimental Watershed (SEW) is a University of Arkansas property of approximately 1,250 hectares (ha) in northwestern Arkansas. The SEW occurs on a mantled (regolith-covered) karst and is the site of an integrated research effort between the University of Arkansas, Arkansas Department of Environmental Quality, Agricultural Research Service of the U.S. Department of Agriculture, and the U.S. Geological Survey. As part of the integrated research effort, a long-term, interdisciplinary field laboratory will be developed for the in-situ quantitative determination of processes, controls, and hydrologic and nutrient-flux budgets in surface-water, soil-water, and shallow ground-water environments in response to specific, near-surface confined animal operation (CAFO) activities and land uses. Comprehensive research at SEW encompasses the detailed aspects of flow and solute budgets (1) from precipitation, (2) from near-surface anthropogenic activities, (3) in runoff, (4) from within the soil zone, (5) at the epikarst, (6) from within identifiable components of the shallow karst aquifer, and (7) at spring resurgences. This presentation is limited to selected elements of budget terms (5), (6), and (7), with the objective of relating areal, stratigraphic, and temporal variations in water quality to identifiable CAFO activities and to ground-water processes and controls. Current CAFO activities in basin 1 at SEW have focused on cattle and poultry.

Continuous hydrologic monitoring at SEW includes measuring precipitation in 0.01-inch increments, and measuring interflow, epikarst flow, streamflow, water levels in selected wells, spring discharge, and appropriate water-quality parameters, all at 15-minute increments with automated probes and samplers. Discrete samples of groundwater from the previously mentioned sources are also collected throughout selected storm hydrographs (at about 1-hour increments) for analyses of water-quality constituents not easily measured by existing sensors. These data provide a wealth of information that allows mass-balance calculations, boundary-flux determinations, and water-quality evolution, all within a well-constrained areal and temporal framework amenable to numerical simulation at a site-specific scale.

Understanding gained at SEW has been applied to studies of CAFO sites elsewhere in the mantled-karst areas of the southern Ozarks, and has been used to guide data-collection rationale. Preliminary conclusions of interest are:

1) Temporally random sampling not keyed to specific hydrologic flow conditions is of little value, and does not characterize important transport features of the system;
2) Sampling from springs in karst terranes integrates the most important components of the flow system, as contrasted to sampling from wells, which typically are indicative of only a single flow component;
3) Dissolved nitrate concentrations in ground water from CAFO areas of northwest Arkansas range from 0.5 to greater than 50 milligrams per liter (mg/L). Most nitrate concentrations in ground water are less than 5 mg/L, and most of the concentrations greater than 20 mg/L have been traced to failed septic systems, and not CAFO sources;
4) Dissolved phosphorous species in ground water typically are less than 0.5 mg/L. Ground-water flow paths do not appear to be major pathways of dissolved phosphorus transport in this hydrogeologic setting;
5) Pathogen densities in ground water are dependent on flow conditions, and have been observed to range from less than 10 to greater than 500,00 colony forming units per 100 milliliters (cfu/100 mL) from the same spring. Pathogen transport in karst aquifers appears to involve resuspension of microbes from the sediment, with highest concentrations occurring at the leading edge of flood pulses; and
6) Pharmaceuticals from CAFO areas are transported in ground water, but the concentrations measured thus far in Northwest Arkansas are below the microgram per liter level.

---

[1] University of Arkansas, 118 Ozark Hall, Fayetteville, AR 72701 (jbrahana@jungle.uark.edu)
[2] National Soil Tilth Laboratory, 2150 Pammel Drive, Ames, IA 50011-4420 (sauer@nstl.gov)
[3] U.S. Geological Survey, 401 Hardin Road, Little Rock AR 72211-3528 (pdhays@usgs.gov)
[4] Arkansas Department of Environmental Quality, 8001 National Drive, Little Rock, AR 72209
[5] University of Arkansas, Fayetteville, AR 72701 (pr101@comp.uark.edu)
[6] U.S. Geological Survey and University of Arkansas, Fayetteville, Arkansas (jefunkho@usgs.gov)

Topical Session B: Human Health and Air and Water Quality

Air Quality Around Animal Feeding Operations

Jerry L. Hatfield [1], *Richard L. Pfeiffer* [2], *and John H. Prueger* [3]

Air quality has become one of the primary issues surrounding the development and operation of animal feeding operations. These concerns range from nuisance due to odor complaints to health associated with small-sized particulates (2.5 millimeters). However, there are many unknowns about air quality surrounding animal feeding operations. Some of these unknowns are: type and amount of gases and particulates that are emitted, effect of changing management systems on the emission and dispersion rates, effect of changing atmospheric conditions on the emission and dispersion rates, and effect of seasonal changes on the emission and dispersion characteristics.

We have been evaluating methods to measure air quality around animal feeding operations. These methods include those that trap the gases in a volume of air and those attached to particulates. These different constituents have been captured on organic absorbing materials and on foam plugs. The constituents captured on these media can be extracted and quantified on a gas chromatograph/mass spectrometer to identify the different volatile organic compounds emitted from buildings and manure-storage units. These techniques have been used to measure air quality around swine production units and have revealed that there are five major classes of compounds present in the air volume: acids, indoles, phenols, cresols, and disulfides. These compounds are in addition to ammonia, methane, nitrous oxide, and hydrogen sulfide. Dispersion characteristics of the atmosphere are the major determinants in changing concentrations downwind from the source. These determinants have also proven to be one of the major challenges in placing the sampling equipment in the plume in order to represent the proper conditions. Sampling of air has proven to be a critical part of the development of methods for quantifying air quality.

Air quality that emanates from buildings is different than from manure-storage units. Data were collected around lagoons in Iowa and Oklahoma to evaluate the changes in the microclimate and the emission rates of volatile organic compounds. The microclimate, air temperature, relative humidity, and windspeed were a function of the position around the lagoon and changed throughout the year. Short-term observations of the turbulent fluxes on the side and from the middle of a lagoon have been used to demonstrate how air patterns move across the lagoon and disperse the compounds emitted from the lagoon surface. These changes can have a major impact on the dispersion patterns around the lagoon. These data, coupled with the observations of volatile organic compounds, show that air quality is rapidly changing around livestock-production facilities. Unfortunately, there are no long-term observations of air quality in animal feeding operations that can be used to develop a baseline of emissions.

---

[1]U.S. Department of Agriculture-Agricultural Research Service, National Soil Tilth Laboratory, 2150 Pammel Drive, Ames, IA 50011-3120 (hatfield@nst1.gov)

[2]U.S. Department of Agriculture-Agricultural Research Service, National Soil Tilth Laboratory, 2150 Pammel Drive, Ames, IA 50011-3120 (pfeiffer@nst1.gov)

[3]U.S. Department of Agriculture-Agricultural Research Service, National Soil Tilth Laboratory, 2150 Pammel Drive, Ames, IA 50011-3120 (prueger@nst1.gov)

Environmental and Public-Health Risks Associated with Industrial Swine Production

Amy R. Chapin[1] *and Charlotte M. Boulind*[2]

Currently, the swine industry is moving further away from traditional methods of hog farming, adopting assembly-line methods of large-scale production where hog farms have metamorphosed into swine factories. In Oklahoma alone, the hog population has soared 761% from 1990 to 1998. Meanwhile, the number of hog operations nationwide has steadily declined from 3 million in the 1950s to 138,000 in 1998. Thus, instead of being spread out among family farmers, U.S. pork production is taking place in a concentrated fashion, creating numerous environmental health concerns. Odors, gases, and solid wastes emitted from these factories have drastically altered the quality of life in neighboring communities. In addition, occupational illnesses, such as asthma, bronchitis, toxic organic dust syndrome, hyperactive airway disease, and hydrogen sulfide intoxication have been reported.

This study investigated the environmental and public-health risks associated with industrial swine production. Literature searches and personal interviews were conducted to assess the issue. Findings revealed that the effects of these swine factories are far reaching. Besides the odor and gases, nearby residents have to cope with an increasing number of flies, rats, and other scavenging animals. Improperly managed manure wastes and pre-slaughterhouse carcasses also threaten the water quality in “hog communities.” Moreover, the close proximity of humans to these facilities raises concerns that certain infectious diseases may cross over from hogs to humans. In addition, there is new evidence that the necessary use of antibiotics in industrial swine production could be contributing to the increase of antibiotic resistance in human pathogens.

Oftentimes, rural public health issues are overlooked. Meanwhile, the rate at which livestock production is shifting into an industrial process, regardless of the environmental, social, and public health consequences, is alarming. This study sought to shed light on this important rural issue as well as offer solutions regarding the ways in which environmental and public-health problems associated with industrial swine production may be remedied.

---

[1]Kerr Center for Sustainable Agriculture, 110 W. 39th Street, # 1216, Baltimore, MD 21210 (chapina@dhmh.state.md.us)

[2]Yale University, New Haven, CT 06520 (Charlotte.boulind@yale.edu)

Reduction of Odor Gases from Cattle Manure with Chemical Additives

V. H. Varel[1] and D.N. Miller[2]

In order to reduce odor emitted from livestock manure, the microbial populations responsible for producing the odorous fermentation end products must be controlled. Odorous compounds are produced from an incomplete fermentation of the organic substrates in manure. Even under optimum conditions, complete fermentation of manure produces the greenhouse gases--methane and carbon dioxide. The environmental conditions that livestock manures are exposed to are unpredictable, and manure-handling systems vary greatly. Thus, microbial manure fermentation is difficult to predict and usually results in a variety of odorous and greenhouse-gas emissions. Therefore, the fermentation should be inhibited before the odorous gases are produced. The objectives of our studies were to evaluate a variety of naturally produced chemicals, which inhibit the microbial fermentation of stored manure. Duplicate one-liter stoppered flasks with a 500-milliliter working volume were used in a series of experiments with beef cattle manure (urine and feces) to evaluate chemicals that reduced total gas and volatile fatty-acid production. Over 20 antimicrobial chemicals were evaluated separately and in combination. A combination of a cationic agent, halogenic carboxylic acid, and a plant essential oil reduced the volatile fatty acids and gas volume after 27 days, 50% and 80%, respectively, when compared with controls. Further studies are needed to determine which volatile organic compounds are reduced. We conclude that various naturally produced additives can be added to manure, which will reduce odorous and greenhouse gases, conserve nutrients in manure that are valuable as plant fertilizer, and potentially reduce pathogenic microorganisms.

[1]U.S. Department of Agriculture, Agricultural Research Service, U.S. Meat Animal Research Center, P.O. Box 166, Clay Center, NE 68933-0166 (varel@email.marc.usda.gov)

[2]U.S. Department of Agriculture, Agricultural Research Service, U.S. Meat Animal Research Center, P.O. Box 166, Clay Center, NE 68933-0166 (miller@email.marc.usda.gov)

Determination of the Potential Toxicity of Contaminants in the Water Requires Improving the Understanding of Low-Concentration Effects

Gary A. Boorman[1], *Samuel H. Wilson*[2], *and Robert C. Sills*[3]

The identification of contaminants, often at very low concentrations, in ground, surface, and drinking water raises concern. Toxicology studies and risk assessment on water contaminants are done at unusually high levels of exposures. Usually, rodent studies use a maximum level of tolerated exposure with several lower concentrations at one-half to one-fourth of the maximum concentration. The results must then be extrapolated from the toxic levels tested to the potential health effects of environmental concentrations. The linear extrapolation used to extrapolate from high to low concentrations has some serious defects. First, it assumes the mechanism of toxicity at high concentrations is similar to the mechanisms of toxicity at lower concentrations. However, for several chemicals, including chloroform, this is simply not the case. The carcinogenicity found at high concentrations is a reflection of repeated cellular toxicity. Second, linear extrapolation assumes that the response to toxicants at low-dose concentrations is similar to the response to high concentrations where adverse health effects are known. Linear extrapolations ignore the fact that cells can repair damage and can respond to minimally toxic exposures. These repair and response systems are necessary because normal cellular processes create endogenous toxicants such as free radicals. Thus, the body has evolved many ways in which to protect itself from many otherwise potent toxicants. These low-dose protection systems potentially provide for a threshold below which exposure has little consequence and above which there could be health problems. It is only when an exposure level is high enough to overwhelm the body's innate protection system that adverse health effects occur.

The National Institute of Environmental Health Sciences (NIEHS) and the National Toxicology Program (NTP) are investigating the molecular pathways of toxicant action and the mechanisms by which the body repairs damage from toxicants. Such knowledge is crucial to the interpretation of the rodent studies at high concentrations. This new research opportunity stems from the dramatic increase in our understanding of biological mechanisms at the cellular and molecular levels and the corresponding increase in our capabilities in the area of analytical chemistry. For example, it is possible to measure DNA damage by quantification of adducts with great precision examining the response to chemicals at low concentrations. Further, quantification of various cellular DNA repair systems has now become standard. Incorporation of relevant mechanistic research from all exposures into the risk-assessment enterprise will reduce uncertainties and produce more accurate and realistic estimates of human risk. While toxicologists are more comfortable working at toxic levels, a paradigm shift will be required to focus on the lower more relevant concentrations. The NIEHS/NTP currently is working on a targeted low-dose/threshold research initiative because the state of the science now allows for such an undertaking. The ultimate goal is to ensure that exposure standards truly protect the health of the public and are based on sound science.

---

[1]National Institute of Environmental Health Sciences, Environmental Toxicology Program, P.O. Box 12233, 101 S. Campus, Rm B-350, Mail Drop B3-08, Research Triangle Park, NC 27709 (boorman@niehs.nih.gov)

[2]National Institute of Environmental Health Sciences, Environmental Toxicology Program, P.O. Box 12233, 101 S. Campus, Rm B-350, Mail Drop B3-08, Research Triangle Park, NC 27709 (wilson5@niehs.nih.gov)

[3]National Institute of Environmental Health Sciences, Environmental Toxicology Program, P.O. Box 12233, 101 S. Campus, Rm B-350, Mail Drop B3-08, Research Triangle Park, NC 27709 (sills@niehs.nih.gov)

Topical Session C: Pathogens

Salmonella and Other Enterobacteriaceae in Dairy Cow Feed Ingredients and Their Antimicrobial Resistance

Riam S. Kidd[1], Annette M. Rossignol[2], Michael J. Gamroth[3], and Norma J. Corristan[4]

Introduction:

Antimicrobial resistant Enterobacteriaceae might be introduced into dairy cows through the consumption of feeds, and the microbes may eventually enter the human food supply.

Members of the Enterobacteriaceae family are becoming more important in food safety and medicine. Estimates of medical and lost productivity costs associated with *Salmonella* species and *Escherichia coli* O157 ranged from $0.2 to 3.5 billion in 1996. Additionally, *Escherichia*, *Klebsiella*, *Enterobacter*, *Serratia,* and *Citrobacter* are responsible for almost one-third of nosocomial infections in the United States (1990-92 data).

Several studies have suggested an association between antimicrobial use in animal feeds and the possible risk of humans contracting resistant bacterial strains such as *Salmonella* spp., *E. coli,* and other enteric infections from food-producing animals. Other studies have isolated different types of *Salmonella* spp. from animal feeds and other feed products. Veldman and others, for example, tested poultry feeds and feed components (fish meal, meat/bone meal, tapioca, maize grits) from 57 feed mills. Among the isolated bacteria, the most frequent serotype was *Salmonella hadar*. Harris and others tested swine feed and feed ingredients (grain, soybean meal, milk/whey, fats/oils, and protein products). The most frequent serotype isolated was *Salmonella worthington*.

Because of sparse data on antimicrobial resistant *Salmonella* spp. and other enteric bacteria in animal feeds and from dairy farms, the objectives of this study include the following:

1. Identify *Salmonella* spp. and other Enterobacteriaceae in dairy cow-feed-ingredient piles on the farms and their antimicrobial-resistance patterns.
2. Determine the prevalence of *Salmonella* spp. in the piles.
3. Determine whether the prevalence of *Salmonella* increases in individual piles over time.

Methods and Materials:

Thirty-two farms were selected at random from 43 commodity dairy feeding farms. Of the 32 farms selected, 12 farms agreed to participate in the study. In the prevalence survey, 50 feed-ingredient piles were sampled for the presence of bacteria. In the repeated samples survey, 10 of the original 50 piles were sampled over time. Presumptive *Salmonella* positives (Assurance EIA *Salmonella* kit) were evaluated further using cultural methods and the Enterobacteriaceae Micro-ID system. A disk-diffusion method was used to identify ampicillin, chloramphenicol, ciprofloxacin, streptomycin, and tetracycline resistance.

Results:

In the prevalence study, 42.0 % (21/50) of the 50 feed-ingredient piles were presumptive positive for *Salmonella*. By the culture method and Enterobacteriaceae Micro-ID system, 2.0 % (1/50) was confirmed as *Salmonella enteritidis* and serogrouped as poly Group B, Group $C_{1.}$ In the repeated samples study, 60.0 % (6/10) of the piles were presumptive positive for *Salmonella*. By the culture method and the Enterobacteriaceae Micro-ID system, 20.0 % (2/10) were confirmed as *Salmonella enteritidis* and serogrouped as poly Group B, Group C1. Fifty bacterial isolates were tested for antimicrobial resistance. Sixty-two percent (31/50) of the isolates demonstrated ampicillin resistance while 10.0 % (5/50) displayed tetracycline resistance.

Conclusions:

The presence of antimicrobial resistant Enterobacteriaceae in feed ingredients raises concerns about health risks to food-producing animals such as dairy cows and subsequently to the consumer.

[1]Oregon Department of Agriculture, 1300 9th Avenue, SW, Albany, OR 97321 (kidd@proaxis.com)
[2]Oregon State University, Department of Public Health, 322 Waldo Hall, Corvallis, OR 97331 (Anne.Rossignol@orst.edu)
[3]Oregon State University, Department of Animal Health Sciences, 112 Withycombe Hall, Corvallis, OR 97331 (Mike.Gamroth@orst.edu)
[4]Oregon Department of Agriculture, 1207 NW Naito Parkway, 2nd Floor, Portland, OR 97201 (ncorrist@oda.state.or.us)

Swine Hepatitis E Virus Contamination in Hog Operation Waste Streams--An Emerging Infection?

Yuory V. Karetnyi[1], Nelson Moyer[2], Mary J.R. Gilchrist[3], and Stanley J. Naides[4]

Swine Hepatitis E Virus (sHEV) is a recently discovered virus endemic to Midwest hog herds. The proposed zoonotic nature of Asian strains of human HEV (hHEV) and the recent discovery of a clade of human HEV in the United States, with approximately 98% DNA and protein sequence homologies to sHEV, suggest the hypothesis that swine herds are a potential animal reservoir for hHEV. In order to determine whether sHEV is a potential environmental contaminant, we tested water samples collected downstream from hog-farm operations for sHEV by nested reverse transcription polymerase chain reaction amplification (RT-PCR). Thirty-three samples including pit slurries, lagoon influents, lagoons, tile inlets, drainage ditches, tile outlets, a draining creek, and a monitoring well were tested by RT-PCR. Three samples (9%) were positive, including two from waste lagoons and one from a tile outlet draining a field to which manure had been applied. Each sample was collected on a separate farm, two in Iowa and one in Missouri. We next identified three sHEV RT-PCR positive hog-stool samples out of 20 tested from a single Iowa farm. All three positive stools came from 3-month-old hogs. sHEV was confirmed by partial sequencing of RT-PCR amplicon. In order to model the duration of sHEV in the environment, 1% and 10% suspensions of sHEV positive stool were stored in water and phosphate buffered saline, respectively, at -85°C, 4°C, and room temperature. sHEV was detectable by RT-PCR under all conditions at 2 weeks of storage, the longest period tested to date. Therefore, sHEV is present in downstream water waste from hog-farming operations. sHEV may persist in the environment for at least 2 weeks and possibly longer.

---

[1]Division of Rheumatology, Department of Internal Medicine, and the Helen C. Levitt Center for Viral Pathogenesis and Disease, University of Iowa; VA Medical Center; and the University Hygienic Laboratory, University of Iowa, Iowa City, IA 52242 (yuory-karetnyi@viowa.edu)

[2]Division of Rheumatology, Department of Internal Medicine, and the Helen C. Levitt Center for Viral Pathogenesis and Disease, University of Iowa; VA Medical Center; and the University Hygienic Laboratory, University of Iowa, Iowa City, IA 52242 (nelson-moyer@viowa.edu)

[3]Division of Rheumatology, Department of Internal Medicine, and the Helen C. Levitt Center for Viral Pathogenesis and Disease, University of Iowa; VA Medical Center; and the University Hygienic Laboratory, University of Iowa, Iowa City, IA 52242 (mary-gilchrist@viowa.edu)

[4]Division of Rheumatology, Department of Internal Medicine, and the Helen C. Levitt Center for Viral Pathogenesis and Disease, University of Iowa; VA Medical Center; and the University Hygienic Laboratory, University of Iowa, Iowa City, IA 52242 (Stanley_naides@viowa.edu)

A System to Describe Antimicrobial Resistance Among Human and Animal Populations

David A. Dargatz[1], Paula J. Fedorka-Cray[2], Kenneth E. Petersen[3], Linda Tollefson[4], Nora E. Wineland[5], Kathy Hollinger[6], and Marcia Headrick[7]

Global concerns about antimicrobial resistance have grown in recent years and include the agricultural and human-health care arenas. The World Health Organization has seated several consultancy groups to examine the implications of antimicrobial use and resistance development. The National Academy of Sciences also has taken up the issue of antimicrobial use and resistance. Numerous other groups have held public and private meetings to discuss various aspects of antimicrobial resistance. Though there is little consensus regarding the roles of various antimicrobial-use practices in the development of resistance that can impact public health, there is widespread recognition that the issue merits further study and that there is a sense of urgency in our need for more data and information.

To track emerging resistance, the National Antimicrobial Resistance Monitoring System - Enteric Bacteria (NARMS-EB) was established in 1996. The overall system is comprised of two separate components for antimicrobial-susceptibility testing of veterinary and human isolates. Testing of the human isolates component of the system is done at the Center for Disease Control in Atlanta. Testing of the veterinary isolates is conducted by the U.S. Department of Agriculture at the Agricultural Research Service Richard Russell Research Center in Athens, Georgia. *Salmonella* was chosen as the sentinel organism to describe levels of resistance and monitor trends in both systems. Currently, *Campylobacter* and *Escherichea coli* 0157 (when available) also are tested in both systems. Testing for the veterinary NARMS-EB *Salmonella* isolates is conducted using a semi-automated system (Sensititre™, Trek Diagnostics). Plates are custom made with 17 antimicrobials in an MIC format. This system is also used for the *E. coli* O157 isolates. *Campylobacter* susceptibility testing to seven antimicrobial drugs is done using the E-test (AB BIODISK). Testing for the human NARMS-EB isolates is conducted using the same testing methodologies and antimicrobials as those used for the veterinary isolates. Veterinary isolates represent a broad range of species and come from diagnostic laboratories, healthy animals on farms, and raw product collected in slaughter or processing plants. The samples from farms are collected as part of the National Animal Health Monitoring System (NAHMS) and represent dairy, beef cow-calf, beef-feedlot, and swine operations.

The goals and objectives of the monitoring program are to (1) provide descriptive data on the extent and temporal trends of antimicrobial susceptibility in *Salmonella* and other enteric organisms from the human and animal populations; (2) facilitate the identification of resistance in humans and animals as it arises; (3) provide timely information to veterinarians, physicians, and others; (4) prolong the life span of approved drugs by promoting prudent and judicious use of antimicrobials; and (5) identify areas for more detailed investigation. Information resulting from the monitoring program and follow-up outbreak investigations will be distributed to veterinarians, physicians, and food animal producer groups in a timely manner. Use of the information will be targeted to redirecting drug use so as to diminish the development and spread of resistance over the short term with directives involving long-term use developed in collaboration with the appropriate professional practitioner groups. Outbreak investigations and field studies will be initiated as a result of major shifts or changes in resistance patterns in either animal or human isolates.

---

[1]U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Centers for Epidemiology and Animal Health, 555 South Howes Street, Fort Collins, CO 80521 (david.a.dargatz@usda.gov)

[2]U.S. Department of Agriculture, Agricultural Research Service, P.O. Box 70, Ames, IA 50010-0000 (pcray@nadc.ars.usda.gov)

[3]U.S. Department of Agriculture, Food Safety and Inspection Service, 6913 Franklin Ct., 1400 Independence Ave., SW, Washington, DC 20250

[4]U.S. Food and Drug Administration, Center for Veterinary Medicine, 7500 Standish Place, Rockville, MD 20855 (ltollefs@cvm.fda.gov)

[5]U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Centers for Epidemiology and Animal Health, 555 South Howes Street, Fort Collins, CO 80521

[6]U.S. Food and Drug Administration, Center for Veterinary Medicine, 7500 Standish Place, Rockville, MD 20855 (kholling@cvm.fda.gov)

[7]U.S. Food and Drug Administration, Center for Veterinary Medicine, 7500 Standish Place, Rockville, MD 20855 (mheadric@cvm.fda.gov)

Microbial Sources Tracking

Mansour Samadpour[1]

The lack of appropriate methodology for tracing bacterial contamination in the environment is a major impediment in identification and control of the sources of these pollutants and adversely affects the decision-making process in water-quality and fisheries-resources management. Several methods for tracking genetically engineered microorganisms have been used, but their utility is limited to the detection of organisms carrying reporter genes or their products. Limited efforts to track sources of natural bacterial populations have been made; the approach used was based on quantification of indicator organisms at various sites. These studies invariably have raised more questions than answers. I have developed and tested a tracking system for identification of sources of microbial pollution. The methodology can be used to identify and assess the impact and contribution of nonpoint sources of microbial pollution and to establish and characterize the impact of the point sources of microbial pollution in fecal runoff. The method can be used to identify the sources of fecal coliforms at the species level and map their distribution, transport, and movement in watersheds, rivers, lakes, and drinking-water-distribution systems. Microbial sources tracking studies conducted in a closed watershed, a swimming beach, and an industrial wastewater-treatment plant will be presented and discussed.

---

[1]University of Washington, Department of Environmental Health, School of Public Health and Community Medicine, Seattle, WA 98195 (mansour@u.washington.edu)

Investigation of the Chemical and Microbial Constituents of Ground and Surface Water Proximal to Large-Scale Swine Operations

Enzo R. Campagnolo[1], Russell W. Currier[2], Michael T. Meyer[3], Dana Kolpin[4], Kendall Thu[5], Emilio Esteban[6], and Carol S. Rubin[7]

Continued expansion and intensification of large-scale swine operations in the United States have brought about some important environmental, agricultural, and public-health issues. Waste-management practices for these operations commonly utilize open earthen lagoons, ponds, or slurry tanks for the temporary storage of manure in a liquefied form, which is subsequently applied as fertilizer on agricultural fields. This practice, under certain conditions, may contaminate the ground and surface water in the surrounding area. Research on the direct and indirect human-health effects of this contamination is very limited. We conducted a pilot investigation on the chemical and microbial constituents of ground and surface water proximal to large-scale swine operations in the State of Iowa. We measured potential chemical (pesticides, antibiotics, heavy metals, minerals, and nutrients) and microbial (*Escherichia coli*, *Salmonella sp.*, *Enterococcus sp.*, *Yersinia sp.*, *Campylobacter sp.*, *Cryptosporidium parvum*) contaminants that may be hazardous to human health. The study accomplished its primary goal of obtaining a broad profile of the chemical and microbial constituents of both ground and surface water proximal to large-scale swine operations. We identified chemical pollutants and zoonotic pathogens in the environment on and proximal to these operations. However, the sample-collection sites were not in locations that could pose a direct threat to human health. More research is needed to accurately determine the level of risk, pathways of exposure, and critical control points to avoid any potential exposure; follow-up investigations are being considered in the near future.

---

[1]National Center for Environmental Health, Centers for Disease Control and Prevention, 4770 Buford Highway, N.E., MS F-46, Atlanta, GA 30341-3724 (ejc5@cdc.gov)

[2]Iowa Department of Public Health, Lucas State Office Bldg., Des Moines, IA 50319-0075 (Rcurrier@idph.state.ia.us)

[3]U.S. Geological Survey, 3916 Sunset Ridge Road, Raleigh, NC 27607 (mmeyer@usgs.gov)

[4]U.S. Geological Survey, P.O. box 1230, Iowa City, IA 52244 (dwkolpin@usgs.gov)

[5]Northern Illinois University, Dept. of Anthropology, 202C Stevens, DeKalb, IL 60115 (Kthu@niu.edu)

[6]National Center for Infectious Diseases, Centers for Disease Control and Prevention, MS G24, Division of Bacterial and Mycotic Diseases, Atlanta, GA 30333 (Jav9@cdc.gov)

[7]National Center for Environmental Health, Centers for Disease Control and Prevention, 4770 Buford Highway, N.E., MS F-46, Atlanta, GA 30341-3724 (chr1@cdc.gov)

Identification of Sources of Fecal Coliform Bacteria and Nutrient Contamination in the Shoal Creek Basin, Southwestern Missouri

J.G. Schumacher[1], *J.L. Imes*[2], *and C.A. Carson*[3]

Missouri is a leader in the Nation in livestock and poultry production. According to the U.S. Department of Agriculture (USDA) 1997 Census of Agriculture, Missouri ranks second in the Nation in the number of beef cattle, sixth in the Nation in the number of hogs and horses, and 11th in the Nation in the number of broilers, pullet chicks, and pullets sold. Much of the beef and poultry production is concentrated in the southwestern part of the State in Barry and Lawrence Counties. From 1992 to 1997, beef-cattle production in Barry County increased in rank from 154th to 92nd in the Nation with more than 41,000 beef cattle inventoried in 1997. Broiler production increased during this same period, and Barry County increased in rank from 32nd to 20th in the Nation with more than 56 million broilers sold during 1997. Recent (1998) estimates place the number of broilers in Barry County between 90 and 100 million.

The rapid growth in the livestock and poultry industries has caused concern about impacts on surface- and ground-water quality in southwestern Missouri. Shoal Creek drains much of the intense beef-cattle and poultry-producing areas of Barry and adjacent counties, and more than 500 poultry houses are located within the upper 233 mi^2 (square miles) of the basin. Between 1992 and 1999, concentrations of fecal coliform bacteria in water samples collected by the Missouri Department of Natural Resources from the upper reach of Shoal Creek averaged more than 5,000 colonies per 100 mL (milliliters). These concentrations greatly exceed the Missouri limit of 200 colonies per 100 mL for the stated uses of Shoal Creek and have resulted in the upper Shoal Creek basin being placed on the 303(d) list of impaired water bodies in Missouri. The U.S. Geological Survey, U.S. Environmental Protection Agency, Region VII, and Missouri Department of Natural Resources recently (1999) initiated a cooperative study to identify the sources of bacterial contamination in Shoal Creek. This multi-discipline investigation combines standard water-quality assessment tools with emerging techniques, including microbial source tracking of *Echerichia coli* using ribotyping and pulse-field electrophoresis; identification of *Salmonella* by culture; and the determination of concentrations of optical brighteners, antibiotics, and hormones in water samples. A network of stream and tributary sites is being monitored monthly for discharge, field parameters, distribution of indicator bacteria, nutrients, and optical brighteners. An expanded suite of analytes including hormones, antibiotics, and major ions are being collected quarterly from all surface-water sites, four springs, and selected sites during storm events. Preliminary results suggest that the largest bacteria densities are not associated with known sewage treatment plant effluents. Of the one dozen *Escherechia coli* isolates initially examined, a single isolate of *E. coli* O157:H7 has been identified from a tributary site outside the Shoal Creek basin.

---

[1]U.S. Geological Survey, MS 100, 1400 Independence Road, Rolla, MO 65401 (jschu@usgs.gov)

[2]U.S. Geological Survey, MS 100, 1400 Independence Road, Rolla, MO 65401 (jimes@usgs.gov)

[3]University of Missouri, Department of Veterinary Pathobiology, Columbia, MO 65211 (CarsonC@missouri.edu)

Topical Session D: Pharmaceuticals

Environmental Considerations for Animal Pharmaceuticals

Charles E. Eirkson III[1]

Animal drugs and feed additives are routinely used in high production agricultural animals. They can be used for therapeutic, production, or nutritional purposes and be administered for a short or extended period. Some drugs and additives may be completely metabolized to inactive components but some are excreted as active metabolites or parent substance. All of these residues are contained in the animal waste from cattle, swine, poultry, and fish facilities. Runoff and leaching from feedlots or aquaculture facilities can carry the remaining substances into surface and ground water. Manure and litter also are used or disposed of on land where it is incorporated into soil. Runoff and leaching to surface and ground water from land applications could also occur. The U.S. Food and Drug Administration, Center for Veterinary Medicine has conducted environmental reviews of many animal drug products. The reviews include information (for example, aqueous solubility and soil sorption) that can be used to determine the potential for a drug to enter surface or ground water. Additional information (for example, acute invertebrate toxicity and plant toxicity) often is collected that can be used to determine potential environmental toxicity. These data are used in environmental-risk assessments to estimate environmental impacts for the animal drug products.

---

[1]U.S. Food and Drug Administration, Center for Veterinary Medicine, 7500 Standish Place, Rockville, MD 20855 (ceirkson@cvm.fda.gov)

Occurrence of Antibiotics in Liquid Waste at Confined Animal Feeding Operations and in Surface and Ground Water

Michael T. Meyer[1], J.E. Bumgarner[2], J.V. Daughtridge[3], Dana Kolpin[4], E.M. Thurman[5], and K.A Hostetler[6]

Radioimmunoassay and immunoassay tests were used to screen for five classes of antibiotics in liquid waste from confined animal feeding operations and in surface and ground water. Approximately one-half of the fifty million pounds of antibiotics produced annually in the United States is for agriculture, with the majority used as feed additives for growth promotion. One or more classes of antibiotics were detected in the liquid waste collected from eight hog lagoons. Tetracycline was the most frequently detected class of antibiotics followed by the sulfonamides, beta-lactams, and macrolides. Estimated concentrations of individual antibiotic screens of samples from the hog-lagoon samples ranged from less than 1 to more than 700 micrograms per liter (μg/L). In ground water, the tetracycline class of antibiotics was detected in a well sample collected near a hog lagoon, and the sulfonamide class was detected in another well sample near a different hog lagoon. The tetracycline class of antibiotics was tentatively detected in 1 of 13 surface-water samples at a concentration less than 1 μg/L. The presence of chlortetracycline in the liquid waste and the surface-water samples that responded positively to the tetracycline radioimmunoassay was confirmed on a subset of samples by using liquid chromatography/mass spectrometry with on-line, solid-phase extraction. The data from this study indicate that antibiotics are present in waste generated at confined animal feeding operations and may be available for transport into surface and ground water. These data indicate that methods with lower detection levels may be needed to study the occurrence of antibiotics in surface and ground water.

---

[1]U.S. Geological Survey, 3916 Sunset Ridge Road, Raleigh, NC 27607 (mmeyer@usgs.gov)
[2]U.S. Environmental Protection Agency, MD-44, Research Triangle Park, NC 27711 (bumgarner.joseph@epa.gov)
[3]U.S. Environmental Protection Agency, MD-44, Research Triangle Park, NC 27711 (daughtridge.joel@epa.gov)
[4]U.S. Geological Survey, P.O. Box 1230, Iowa City, IA 52244 (dwkolpin@usgs.gov)
[5]U.S. Geological Survey, 4821 Quail Crest Place, Lawrence, KS 66049 (ethurman@usgs.gov)
[6]U.S. Geological Survey, 4821 Quail Crest Place, Lawrence, KS 66049 (khostet@usgs.gov)

Pharm-Chemical Contamination: A Reconnaissance for Antibiotics in Iowa Streams, 1999

Dana Kolpin[1], David Riley[2], Michael T. Meyer[3], Peter Weyer[4], and E.M. Thurman[5]

About 90 percent of the roughly 2.5 million kilograms of antibiotics used for livestock production in the United States each year are given as growth-promoting and prophylactic agents rather than to treat active infections. These subtherapeutic levels of antibiotics are one of the factors that have allowed the confinement of animals in large production facilities, thereby lowering the costs of animal care. There has been increasing public concern, however, that this widespread antibiotic use may lead to contamination of the Nation's ground and surface waters -- increasing the potential for the creation of antibiotic-resistant bacteria that could pose a risk to human health.

Currently in the United States, there is little known about the occurrence and fate of antibiotics in the hydrologic system. A study was conducted during the spring of 1999 to provide baseline data on the occurrence of antibiotics in streams. A network of 30 streams was selected across Iowa representing basins containing low to intense hog production. Water samples were collected from these streams during the first runoff event following snowmelt (a time when there is an increased likelihood of antibiotic transport to streams). Water samples will be analyzed for a broad spectrum of antibiotics (20-30 compounds) using liquid-chromatography/mass-spectrometry technology. Reporting limits for these compounds are estimated to be between 0.05 and 0.2 microgram per liter.

---

[1]U.S. Geological Survey, P.O. Box 1230, Iowa City, IA 52244 (dwkolpin@usgs.gov)

[2]University of Iowa, Center for Health Effects of Environmental Contamination, 100 Oakdale Campus #N202 OH, Iowa City, IA 52242-5000 (david-riley@viowa.edu)

[3]U.S. Geological Survey, 3916 Sunset Ridge Road, Raleigh, NC 27607 (mmeyer@usgs.gov)

[4]University of Iowa, Center for Health Effects of Environmental Contamination, 100 Oakdale Campus #N202 OH, Iowa City, IA 52242-5000 (peter-weyer@viowa.edu)

[5]U.S. Geological Survey, 4821 Quail Crest Place, Lawrence, KS 66049 (ethurman@usgs.gov)

Analysis of Tetracycline and Sulfamethazine Antibiotics in Ground Water and Animal-Feedlot Wastewater by High-Performance Liquid Chromatography/Mass Spectrometry Using Positive-Ion Electrospray

E. Michael Thurman[1] and K.A. Hostetler[2]

Two classes of antibiotics used in animal feed (tetracyclines and sulfamethazines) are analyzed from ground-water and wastewater samples by high-performance liquid chromatography/mass spectrometry (HPLC/MS) using positive-ion electrospray with a detection limit of 0.2 microgram per liter (μg/L). The method consists of filtering 40 milliliters (mL) of water sample through a 0.45-micron glass-fiber filter followed by acidification with phosphoric acid to pH 2. The sample is passed through a solid-phase extraction (SPE) cartridge (ENV+, polymeric resin) and dried under vacuum. The cartridge then is eluted with 4N NH_4OH in methanol, vortexed, and filtered. SPE recovery is approximately 80%. The eluate then is injected into the HPLC/MS system, which is running a methanol/water gradient from 10 to 80% methanol. The addition of the ammonium hydroxide is critical in the hydrolysis of the various epimers of chlortetracycline. The hydrolysis occurs rapidly, giving one chromatographic peak rather than the six epimeric forms of chlortetracycline. The ions monitored by selected-ion monitoring are 479, 481, and 501 (a sodium adduct) for chlortetracycline and 279, 281, and 301 (sodium adduct) for sulfamethazine. Internal standards are used for quantitation, including tetracycline for chlortetracycline and $^{13}C_6$ sulfamethazine for sulfamethazine. Analysis of several ground-water samples collected near waste lagoons and wastewater-lagoon samples show that the antibiotics are detected readily at microgram-per-liter concentrations.

---

[1]U.S. Geological Survey, 4821 Quail Crest Place, Lawrence, KS 66049 (ethurman@usgs.gov)
[2]U.S. Geological Survey, 4821 Quail Crest Place, Lawrence, KS 66049 (khostet@usgs.gov)

A Reconnaissance for Hormone Compounds in the Surface Waters of the United States

Larry B. Barber[1], Greg K. Brown[2], Dana Kolpin[3], Jeffery H. Writer[4], and Steven D. Zaugg[5]

The occurrence of hormone compounds, such as 17-b-estradiol and testosterone in surface waters, has become a topic of concern because of potential adverse effects including disruption of the endocrine system of aquatic organisms. Sources of hormones to natural waters include disposal of effluents from municipal sewage-treatment plants and animal feeding operations. To evaluate the presence of hormone compounds in surface waters across the United States, a reconnaissance survey was conducted in spring 1999. Samples were collected from 24 streams in 19 States (Arkansas, Colorado, Georgia, Iowa, Illinois, Louisiana, Maryland, Minnesota, Michigan, Missouri, North Carolina, Nebraska, Ohio, Oklahoma, Pennsylvania, Texas, Utah, Washington, and Wisconsin). This survey included 14 streams from basins with intense production of hogs (2), poultry (6), dairy cattle (2), beef cattle (2), and mixed-animal production (2). In addition, streams from nine urban basins (including Denver, Dallas, Minneapolis, and Salt Lake City) and one mixed basin (Mississippi River near St. Francisville, Louisiana) were sampled. The samples were analyzed using continuous liquid-liquid extraction with selected ion monitoring gas chromatography/mass spectrometry (SIM GC/MS). Wastewater contaminants such as nonylphenol and triclosan were detected in 50% of the samples at part per billion concentrations. Specific analysis of steroid hormones using derivatization SIM GC/MS analysis indicated the presence of androgens and estrogens at part per trillion concentrations.

---

[1]U.S. Geological Survey, Box 25046, MS 408, Denver Federal Center, Denver, CO 80225-0046 (lbbarber@usgs.gov)

[2]U.S. Geological Survey, Box 25046, MS 408, Denver Federal Center, Denver, CO 80225-0046 (gkbrown@usgs.gov)

[3]U.S. Geological Survey, P.O. Box 1230, Iowa City, IA 52244 (dwkolpin@usgs.gov)

[4]Centaurus High School, 10300 E South Boulder Rd., Lafayette, CO, 80026

[5]U.S. Geological Survey, Box 25046, MS 407, Denver, CO 80225-0046 (sdzaugg@usgs.gov)

Topical Session E: Nutrients

The views and conclusions contained in this document from authors not affiliated with the U.S. Geological Survey are solely those of the authors and should not be interpreted as necessarily representing the views or official policies, either expressed or implied, of the U.S. Geological Survey.

Hydrogeologic Settings of Earthen Waste Storage Structures Associated with Confined Animal Feeding Operations in Iowa

Michael R. Burkart[1] and William W. Simpkins[2]

Earthen Waste Storage Structures (EWSS) that store waste from animal feeding operations have raised serious concerns about ground-water and surface-water contamination risks. Thirty-four of 639 permitted EWSS in Iowa were investigated to characterize their hydrogeologic setting. Sites were selected to proportionally represent five aquifer vulnerability regions of Iowa. Data used in the analysis included digital-soils data from the Natural Resources Conservation Service, topographic data from the U.S. Geological Survey, and oblique aerial photographs taken at 1,000 feet (ft) altitude.

Nearly 18 percent of the 34 selected sites were constructed over alluvial aquifers. Contaminants reaching these aquifers could affect many water supplies in the State. Sites located on alluvial aquifers also lie in flood plains with a continual risk of flooding and contamination of surface water from manure application and structure failure. High and fluctuating water tables associated with floods may compromise EWSS liners increasing the risk of failure. Large areas within 2 miles of most sites have soils with a saturated permeability of $\geq$ 1 inch per hour (in/hr). These areas also include substantial well-drained soils or moderately- to well-drained soils. The dominance of EWSS depths exceeding 10 ft and areas with water tables less than 5 ft deep, suggests that most sites are below the water table. The frequency of sites with a combination of these indicators of contaminant movement indicates EWSS expose ground water to a substantial risk of contamination. Ephemeral streams were found within 500 ft at 21 percent of the sites, and perennial streams were found within 500 ft at 12 percent of the sites. One site had been built by impounding the valley of a small ephemeral stream, and one was immediately upstream from a major aquatic recreation area. Many sites had unmapped drainageways that led from the EWSS to ephemeral or perennial streams.

Reduction of risks to ground-water and surface-water resources by EWSS may be attained by using siting criteria that incorporate geologic, hydrogeologic, and soils data as outlined in this paper. EWSS sites built on alluvial aquifers should not be permitted unless measures are taken to ensure that the aquifer is not being contaminated. Controlling the timing of manure application and avoiding manure application on frequently flooded soils, such as those on flood plains, may reduce the risk of contamination of ground water and surface water. Application of well established, scientifically defensible ground-water-monitoring techniques should be used to locate the position of the water table during construction and throughout the life of the EWSS. These techniques may help identify whether the recommended hydraulic separation between the EWSS and the water table will be maintained. In many instances, a shallow water table should preclude siting of an EWSS. Setback distances from surface-water courses should be based on local hydrogeologic and topographic conditions. These considerations, used with appropriate construction designs, would reduce the potential for contamination of surface water resulting from seepage, overflow, or failure of EWSS. Uniform setback distances may not be appropriate for all topographic, hydrogeologic, and ecologic settings.

---

[1]U.S. Department of Agriculture, Agricultural Research Service, National Soil Tilth Laboratory, 2150 Pamuel Drive, Ames, IA 50011 (burkart@nstl.gov)

[2]Iowa State University, Department of Geological and Atmospheric Sciences (bsimp@iastate.edu)

Nutrients Available From Livestock Manure Relative To Land Use

David C. Moffitt[1] *and Charles H. Lander*[2]

The U.S. Department of Agriculture in general, and the Natural Resources Conservation Service (NRCS) specifically, are required to conduct a periodic assessment of the state of the Nation's agricultural resources, commonly referenced as the Resource Conservation Assessment (RCA). These assessments vary in degree of complexity and the number of resources assessed, but generally focus on the following five resources--soil, water, plant, animal, and air.

During planning for the third RCA, the leadership of NRCS requested a comprehensive evaluation of the impacts of animal agriculture on the Nation's resources. With the rapid expansion of the poultry and swine industry into traditional locations and new locations, there was a general impression that adequate land resources for manure utilization could be a limiting factor.

This paper will describe the analysis process used to relate manure nutrient availability to the land resource as the animal population and location of production changed from 1992 to 1997. County level livestock numbers from the 1992 and 1997 Census of Agriculture were combined with nationally accepted values of manure characteristics to determine the amount of nitrogen and phosphorus available for use as nutrients in agricultural production. These nutrients were balanced against the potential uptake of nitrogen and phosphorus for agricultural production on acreage, also reported to the Census of Agriculture.

The analysis results in the identification of counties where manure nutrients meet or exceed the nutrient needs of the agricultural production in the county. This paper will conclude with a discussion of the shift in potential problem areas between 1992 and 1997 and the environmental ramifications of these shifts.

---

[1]U.S. Department of Agriculture, Natural Resources Conservation Service, P.O. Box 6459, Fort Worth, TX 76115 (dmoffitt@ftw.nvcs.usda.gov)

[2]U.S. Department of Agriculture, Natural Resources Conservation Service, 14th and Independence Avenue SW, Washington, DC 20250-9410 (charles.lander@usda.gov)

Predicting Surface-Water Impacts from Concentrated Animal Feeding Operations: A National Analysis

Kathy Zirbser[1]

The U.S. Environmental Protection Agency has developed a methodology to quantify national-level water-quality impacts due to nutrient loads from concentrated animal feeding operations (CAFOs). The methodology provides a screening-level analysis of impacts to reservoirs, based on trophic status and hypolimnetic dissolved-oxygen concentration. The methodology incorporates various watershed model results, databases, and water-quality models. The watershed portion of the model is based on the eight-digit hydrologic cataloging unit and utilizes previously published nutrient export estimates generated by the U.S. Geological Survey's SPARROW model. The watershed-export estimates are adjusted using data from a manure-nutrient database, which was developed to estimate the amount of nutrients generated by livestock type and farm size in each watershed. A lake-response model is used to predict long-term responses of hypolimnetic dissolved-oxygen concentrations. A stream model also is being developed to estimate ammonia and dissolved-oxygen concentrations. Effects of policy changes on nutrient runoff are estimated externally, using a field-scale model, and then incorporated into the water-quality analysis.

---

[1]U.S. Environmental Protection Agency, 401 M Street, S.W., Mail Code 4305, Washington, DC 20460 (zirbser.kathy@epa.gov)

Phosphorus Geochemistry in Two Coastal Plain Watersheds with Different Land Management Practives: Processes Involving Organophosphorus Compounds

Nancy S. Simon[1], Jenefir Isbister[2], and Joseph Margraf [3]

Popes Creek, Virginia, is the site of the National Park Service's George Washington Birthplace Monument. The intensity of agricultural activities in this watershed has diminished in this century. The Pocomoke River, Maryland, is the location of major poultry industry where more than 82 million chickens are raised each year. The manure from these chickens is used to fertilize fields in the Pocomoke watershed and water from agricultural fields drains into the upper Pocomoke River. To evaluate the condition of downstream sediments in areas where each stream empties into a larger body of water, box cores were taken of bottom sediment: (1) where Popes Creek empties into the Potomac River, and (2) where the Pocomoke River empties into the Chesapeake Bay.

Box cores were collected in August and November of 1998, and in April 1999, in the Pocomoke River. Box cores were collected in April 1999 in Popes Creek. One to two centimeter intervals of sediment were separated in a nitrogen-filled glove bag. Sediment samples were centrifuged and interstitial water filtered through a 0.2-micrometer membrane. Solids were analyzed for total phosphorus, aluminum, calcium, and iron. Anion analyses of the interstitial water included soluble-reactive phosphate, orthophosphate, chloride, nitrate, and sulfate. Cation analyses of the interstitial water included aluminum, calcium and iron. Concentration gradients from the sediment water-interface to a depth of 20 centimeters show that iron and phosphate concentrations are larger in interstitial water in sediments from Pocomoke River than in interstitial water in sediments from Popes Creek. Because the total phosphorus concentrations in sediments from the two watersheds are similar, a difference in bacterial populations was tested.

The manure of chickens contains phytic acid (inositol hexaphosphoric acid) because chickens can digest less than 30 percent of phytic acid found in the corn in their diets. Microbiological experiments were done to test the response of bacteria in downstream sediments from each watershed to the presence of phosphorus-containing compounds in poultry diets. Incubations of sediment from both watersheds used a medium containing no phosphorus or a medium to which either phytic acid or pyridoxal-5-phosphate, a phosphate-containing compound of the vitamin B-6 complex found in animal feeds, was added as a sole source of phosphorus. Phytic acid or pyridoxal-5-phosphate stimulated the growth of bacteria in sediments from Popes Creek but did not stimulate the growth of bacteria in sediments from the lower Pocomoke River. The sediment from Pocomoke River bacteria were able to grow with, or without, phosphorus in the medium, suggesting that these bacteria are not phosphorus limited.

Similarities and differences in the bacterial population with respect to phosphorus cycling are being investigated. Hypotheses that might explain different responses of the bacterial populations to nutrient adequacy or limitation include: (1) differences in the amount and speciation of phosphorus in the two watersheds, (2) different responses to various nutrient conditions by bacteria in sediments from these two watersheds, (3) differences in redox conditions at sampling sites reflect different bacterial communities, and, (4) antibiotics might be having an affect on microbial populations in the watersheds.

---

[1]U.S. Geological Survey, 432 National Center, Reston, VA 20192

[2]George Mason University, MSN 4D7, Fairfax, VA 22030

[3]U.S. Geological Survey, Maryland Cooperative Fish and Wildlife Research Unit, Princess Anne, MD 21853

Nutrient Imports to Support AFOs in the Black River Basin, North Carolina

Lawrence B. Cahoon[1] and *Michael A. Mallin*[2]

Animal Feeding Operations (AFOs), primarily swine and poultry-production facilities, have become particularly concentrated in the basin of the Black River, a coastal plain tributary of the Cape Fear River in eastern North Carolina. The concentration of AFOs in this small area drives a need for imports from outside the basin of substantial amounts of corn, wheat, and soy meals used as the base of animal feeds. Calculation of net imports of nitrogen and phosphorus, based on net feed material imports and manure nutrient outputs, shows that very high percentages and quantities of these imported nutrients are deposited in the basin. These quantities exceed the amounts of commercial fertilizer used in the basin but have not substantially replaced those fertilizers. Consequently, nutrient imports to the Black River basin now greatly exceed those occurring in the 1980s, with as yet incompletely understood consequences for regional air and water quality. However, studies to date have already documented a variety of impacts that may be attributed to AFOs.

The geographic concentration of AFOs and the consequent net imports of very large amounts of "new" nutrients to small areas pose important management challenges. Efforts should be made to determine the fates of imported nutrients and their impacts on regional ecosystems. Comprehensive nutrient-management plans that incorporate nutrient-export strategies should be considered. Regulatory efforts should include consideration of the spatial and temporal cumulative effects of concentrated AFOs.

---

[1]University of North Carolina, Department of Biological Sciences, Wilmington, NC 28403 (cahoon@uncwil.edu)

[2]University of North Carolina, Center for Marine Science Research, Wilmington, NC 28403 (mallin@uncwil.edu)

Interaction Between Surface and Ground Water in the Transport of Nutrients from Animal Wastes in Karst Terrain

Thomas J. Sauer[1], *J. Van Brahana*[2], *and Timothy M. Kresse*[3]

Animal wastes contain nutrients that, if delivered in sufficient quantities, have potential to negatively impact surface and subsurface water quality. The Savoy Experimental Watershed (SEW) was established as a site for long-term studies of animal-waste impacts on surface and subsurface water quality in karst terrain such as the Ozark Highlands. The SEW is a collaborative effort between the University of Arkansas; U.S. Department of Agriculture, Agricultural Research Service; U.S. Geological Survey; and the Arkansas Department of Environmental Quality and involves an interdisciplinary team of scientists. The most intense monitoring activities have been directed at Basin 1 of the SEW, a 147-hectare watershed immediately adjacent to the Illinois River. Surface cover in Basin 1 is divided between forest (60%) and pasture (40%), and the entire watershed is grazed by beef cattle (*Bos taurus*). Poultry litter (bedding material and manure) is applied at varying intervals and amounts to pastures within the basin.

Weirs were installed on two continuously flowing springs (Langle and Copperhead) adjacent to Basin 1 and at the basin outlet to measure flow and water-quality parameters. Over 20 shallow, 5-centimeter diameter monitoring wells have been installed primarily in alluvial areas near the outlet of Basin 1 while 3 deep [>30-meter (m)] wells allow sampling of the shallow aquifer above the regional confining layer. Additional sampling sites including several small springs, a nearby tributary (Clear Creek) and the Illinois River also are monitored for several water-quality parameters including nitrate (NO_3-N), ammonia (NH_3-N), and dissolved reactive phosphorus (DRP).

Nitrate and DRP concentrations in spring baseflow samples are consistently higher for Copperhead Spring as compared to Langle Spring. This trend may be related to higher animal waste applications in the Copperhead Spring recharge basin. Concentrations for NO_3-N and DRP range from 1 to 9 milligrams per liter (mg L^{-1}) and from 0.02 to 0.05 mg L^{-1}, respectively, with the higher NO_3-N observed during low-flow conditions in late summer. Only very low concentrations of NH_3-N have been detected (<0.005 mg L^{-1}). Samples collected during two storm events in February 1999 indicated that NO_3-N concentrations peak at the leading edge of storm hydrographs. Very little organic N or NH_3-N was transported during these events. Nitrate concentrations ranged from 3 to 8 mg L^{-1} for Copperhead Spring and 1.5 to 3.5 mg L^{-1} for Langle Spring, respectively. Phosphorus concentrations were less than 0.055 mg L^{-1} during the storm events with elevated total P levels early in the storm hydrograph. Dye-tracing studies and analyses of runoff data indicate that surface runoff is routinely captured by both springs and that the degree of capture varies with runoff volume.

Results of monitoring activities at the SEW indicate significant transport of NO_3-N in Basin 1 via surface and subsurface flow paths while low concentrations of DRP in spring and runoff water indicate effective retention of P in soil layers. Low concentrations of sediment-bound N and P suggest that erosion is not a significant factor in nutrient transport within this basin. Langle and Copperhead Springs capture surface runoff, a process that effectively bypasses further nutrient retention by surface soil layers.

---

[1]National Soil Tilth Laboratory, 2150 Pammel Dr., Ames, IA 50011-4420 (sauer@nstl.gov)

[2]University of Arkansas, 118 Ozark Hall, Fayetteville, Arkansas 72701 (jbrahana@jungle.uark.edu)

3 Arkansas Department of Environmental Quality, 8001 National Drive, Little Rock, AR 72209 (kresse@adeq.state.ar.us)

Field Evaluation of Animal-Waste Lagoons: Seepage Rates and Subsurface Nitrogen Transport

J.M. Ham[1]

Earthen lagoons are an integral part of the waste-management plan at many animal feeding operations (AFOs). Lagoon waste contains high concentrations of N, P, salts, and other nutrients that, in many cases, are applied to farmland as liquid fertilizer. However, while the waste is being stored and treated in the lagoon, subsurface-seepage losses may affect soil and water quality near the facility. Research was conducted to develop water-balance methods and instrumentation for measuring whole-lagoon seepage from large-scale, commercial AFOs. Seepage(s) losses were calculated as the difference between changes in waste depth (D) and evaporation (E) when all other inflow and outflow were precluded. Waste-level recorders were developed that could measure D to within 0.16 millimeter (mm). Evaporation was quantified using floating evaporation pans and meteorological models. Different strategies for calculating E and S were compared. Results showed that S from lagoons could be determined to within ± 0.5 millimeter per day (mm d^{-1}) by making precision water-balance measurements over short periods (5 to 10 days), if E was less than 6 mm d^{-1} (Ham, in press).

Water-balance methods were used to study seepage losses and nitrogen export from soil-lined lagoons at ten different swine and cattle feedlots in southwestern Kansas. Lagoons ranged in size from 0.5 to 2.5 hectare (ha) and had waste depths between 1.5 and 5.6 meters (m). Compacted-soil liners were between 0.30 to 0.46 m thick and built with native soil or, in some cases, a soil-bentonite mixture. Seepage rates from the lagoons ranged from 0.02 to 2.5 mm d^{-1} , with an overall average of rate of 1.2 mm d^{-1}. At some locations, seepage results were combined with data on lagoon geometry and liner construction to estimate the in-situ permeability of the compacted liner. In lagoons built with silt loam liners (no bentonite), permeabilities on a whole-lagoon basis were about five times less than those measured from soil cores collected prior to the addition of waste. Results imply that permeability was reduced by organic sludge on the bottom of the lagoons. The average ammonium-N (NH_4^+-N) concentrations in the swine-waste and cattle-feedlot lagoons were 673 and 98 milligrams per liter, respectively. Calculated NH_4^+-N export rates (seepage losses) from the swine waste lagoons were between 2,000 and 3,000 kilograms per hectare per year (Ham and DeSutter, in press). Analysis of soil cores collected beneath 11- to 20-year-old lagoons showed that a large fraction of the NH_4^+-N in the leachate remained in a shallow (for example, 6 m) adsorption zone directly beneath the lagoon. When lagoons are closed, emptied, and dry; NH_4^+-N could convert to nitrate and more readily move towards the ground water. More information is needed regarding the fate of NH_4^+-N deposited in soil (vadose zone) beneath lagoons.

References

Ham, J.M., in press, Measuring evaporation and seepage losses from lagoons used to contain animal waste: Transactions of the American Society of Agricultural Engineers (ASAE).

Ham, J.M., and T.M. DeSutter, in press, Seepage losses and nitrogen export from swine-waste lagoons: a water balance study: Journal of Environmental Quality.

---

[1]Kansas State University, Department of Agronomy, Manhattan, KS 66506 (**snafu@ksu.edu**)

Treating Livestock Manure: Available Technology, Effectiveness, and Costs

Jose R. Bicudo[1] and Jun Zhu[2]

Recycling of livestock manures by land application for plant uptake and crop production is a traditional and proven technique. When properly carried out, targeted land application enabling crop uptake can be the basis of an environmentally safe and friendly method of manure management. However, the pressures on animal farming are increasing every day, and in some cases, existing methods are not adequate for dealing with the environmental problems arising from livestock manure. Farms located close to housing can expect odor nuisance complaints and those near rivers, streams, and lakes are all too aware of the penalties of pollution following runoff or spillage. The problems related to manure production and handling run deeper, with a range of less apparent pollution issues now becoming evident. Of increasing concern is the potential for spread of diseases (air or waterborne) and emissions to air, especially odor of hydrogen sulfide and ammonia.

Processing and/or biological treatment of manure is a step beyond currently accepted good agricultural practice in the Midwest that may be justified only when odor problems or water-pollution risks have been identified in a manure/nutrient management plan. The cost and level of management skill required for the implementation and operation of treatment schemes should not be underestimated and must be added to the cost of collecting, storing, and spreading the manure.

In this paper, we summarize existing information on: (1) alternative treatment technologies for livestock manure (mechanical solid separation, physical-chemical treatment, and biological treatment), (2) effectiveness of systems in reducing odor and gaseous emissions, organic matter (COD, BOD and solids), nutrients (N and P), and bacterial indicators; and (3) systems capital and operational costs.

Although there is still much debate on the advantages and disadvantages of different treatment strategies, a range of perceived benefits may include abatement of odor, stabilization of organic matter and nutrients, improvement of handling characteristics in storage and during spreading, and control of pathogens. The implementation of manure-treatment systems has a clear role in the overall management scheme, but most of these systems remain to be proven as either effective and/or economical enough and practical at the farm level.

---

[1]University of Minnesota, Department of Biosystems and Agricultural Engineering, 1390 Eckles Avenue, St. Paul, MN 55108 (bicud001.umn.edu)

[2]University of Minnesota, Southern Research and Outreach Center, 35838 120th Street, Waseca, MN 56093-4521 (2huxx034etc.umn.edu)

Poster Session

The views and conclusions contained in this document from authors not affiliated with the U.S. Geological Survey are solely those of the authors and should not be interpreted as necessarily representing the views or official policies, either expressed or implied, of the U.S. Geological Survey.

Evaluation of Swine Effluent as a Plant Nutrient Source for Sprinkler Irrigated Corn

Mahdi M. Al-Kaisi[1] *and Reagan M. Waskom*[2]

The expansion of large swine-production facilities in northeastern Colorado prompted a need to evaluate the use of swine effluent as a nutrient source for irrigated corn. The objectives of this study were to compare the impact of swine effluent to similar rates of commercial-N fertilizer on corn performance and N buildup in the soil profile. The 3-year study began in 1995 on a 36-acre sprinkler irrigated site, consisting of sandy to loamy sand soil and planted to field corn (*Zea Mays L.*). The total available nitrogen rate for swine effluent and commercial-N fertilizer treatments are 0, 130, 185, and 235 pounds (lb) N/acre. The fertilizer treatments were replicated three times in a completely randomized design. Ninety percent of the total nitrogen was present as ammonium-N in the effluent of a two-stage lagoon, where the total dry matter content was only 0.1-0.2% by volume. The feed ration and age of pigs grown significantly impacted the effluent content. Corn yield increased an average of 24% under swine effluent as compared to commercial-N fertilizer, resulting in significant soil-N buildup at the 4 to 8-foot depths under the commercial-N fertilizer. This buildup is most likely due to enhanced crop production in response to other nutrients found in the effluent. The total N and P plant uptake was 24% and 55%, respectively, greater under the swine-effluent treatments than under the commercial-N fertilizer treatments. As the swine-effluent-application rate increased, the plant N and P uptake and recovery rate increased.

---

[1]Colorado State University Cooperative Extension, U.S. Central Great Plains Research Station, 40335 County Road GG, Akron, CO 80720 (malkaisi@coop.ext.colostate.edu)

[2]Colorado State University, Department of Soil and Crop Sciences, Fort Collins, CO 80523 (rwaskom@agsci.colostate.edu)

An Inquiry Into the Rationale for Prioritizing South Carolina's Animal Feeding Operations for Water Pollution Regulation

Jeffery Allen[1], Kang Shou Lu[2], and Sean P. Blacklocke[3]

Considering the extent of land-use restrictions and environmental-impact-monitoring requirements associated with operating animal feedlots in South Carolina, our state now arguably leads the nation in regulatory efforts to reduce polluted runoff from these sources. The research presented here is an inquiry into the rationale the South Carolina Department of Health and Environmental Control used in its recent promulgation of new animal agriculture regulations pursuant to the 1996 Hog Act.

Unlike other previous studies, this paper does not investigate or challenge the technical merits of the threshold values chosen for setback distances, lagoon dimensions, animal units, or pollutants monitored, for example. The work questions the rationale for prioritizing South Carolina's animal feeding operations for environmental cleanup in lieu of other sources of water pollution that are known causes of streams not meeting even minimum-acceptable Federal water-quality standards.

The research first summarizes and explains the data used to establish the State's implicit finding that polluted runoff from animal agriculture degrades or poses a potential to degrade water quality in South Carolina to a degree comparable to other sources. Relevant explanatory information made available to the public in promulgating the new regulations consisted primarily of inferences made from national ambient water quality monitoring-data and anecdotal information derived from incidents in other States. No data summaries, case studies, or incidents linking animal agriculture to water pollution in South Carolina could be identified, although a multitude of data are presented that suggest pervasive problems from other specified sources.

Since no studies linking animal feeding operations to nonpoint-source-water pollution in South Carolina could be identified, the research presented here attempts to initiate efforts to determine the absolute and relative contributions of animal feedlots and other sources to the water-pollution problem in South Carolina.

Fecal coliform bacteria and oxygen-depleting compounds are the two constituents in feedlot runoff that are suspected to be polluting South Carolina's waterways; two pollutants that also are common to industrial and municipal point-source discharges and urban-land runoff.

The study uses agricultural census data to map heads of cattle and hogs and chicken farms in South Carolina. Census data also are used to map human-population concentrations in the State. Watersheds containing streams prioritized for reductions in fecal-coliform pollution or oxygen-depleting pollutants are mapped and overlain with the animal/human data.

Eight maps relating water pollution, animal agriculture, and urban areas in South Carolina are presented. The maps are categorized into two broad groupings; animals and humans related to dissolved oxygen stream impairment and animals and humans related to fecal coliform bacteria stream impairment. In general, there seems to be a high presence of fecal coliform and oxygen-depleting pollutants in the State's streams that lie in urban watersheds and a very low occurrence in the regions of the State that harbor agricultural animals.

---

[1]South Carolina Water Resources Center, The Strom Thurmond Institute, P.O. Box 345203, Clemson University, Clemson, SC 29634-5203 (jeff@strom.clemson.edu)

[2]South Carolina Water Resources Center, The Strom Thurmond Institute, P.O. Box 345203, Clemson University, Clemson, SC 29634-5203 (klu@strom.clemson.edu)

[3]South Carolina Water Resources Center, The Strom Thurmond Institute, P.O. Box 345203, Clemson University, Clemson, SC 29634-5203 (Sean@strom.clemson.edu)

Time-Series Sampling for Nutrients and Bacteria in Ground Water at Four North Florida Dairy Farms and Three Springs Along the Suwannee River, 1990-93

William J. Andrews[1]

Nitrate concentrations exceeded the primary drinking-water standard of 10 milligrams per liter as nitrogen in water samples from 24 of 51 monitoring wells sampled periodically from 1990-93 at 4 dairy farms in Lafayette and Suwannee Counties in northern Florida. The greatest concentrations of nitrate were detected in ground water from monitoring wells with 10-foot screens completed at the water table located downgradient from unlined wastewater lagoons and defoliated areas of intensive cattle use. Water from wells completed 10 feet deeper in the saturated zone, wells completed in areas with lower waste-loading rates (such as pastures), and wells located upgradient of wastewater lagoons and intensive-use areas had lesser concentrations of nitrate, but nitrate concentrations in water from those wells generally exceeded those from ambient-network wells sampled in the area by the Florida Department of Environmental Protection. Nitrate concentrations in water discharged to the Suwannee River from three springs in the vicinity of those and other dairy farms ranged from 2 to 7 milligrams per liter, which also was greater than nitrate concentrations in water sampled from ambient-network wells.

Most of the wells produced water containing dissolved oxygen, which favors the formation of nitrate (nitrification) from organic and ammonium compounds of nitrogen. Concentrations of organic and ammonium nitrogen generally were much less than nitrate concentrations. Phosphorus and orthophosphate-phosphorus concentrations were similar to concentrations measured in water samples from ambient-network wells. To investigate the potential for denitrification (reduction of nitrate to nitrous oxide or dinitrogen gases), counts of denitrifying bacteria were made in water from selected monitoring wells. Counts of those bacteria commonly exceeded 10,000 colonies/100 milliliters, but because most water samples contained dissolved oxygen, denitrification probably does not occur in shallow ground water in the area. Counts of fecal coliform and fecal streptococcal bacteria in water samples from selected wells commonly exceeded 1,000 colonies per 100 milliliters.

---

[1]U.S. Geological Survey, 202 N.W. 66th Street, Oklahoma City, OK 73116 (wandrews@usgs.gov)

Comparison of Water Quality in Four Small Watersheds Containing Animal Feeding Operations in Iowa, 1996-98.

Kent D. Becher[1] *and Kimberlee K.B. Akers*[2]

Agriculture constitutes 93 percent of all land use in Iowa, and Iowa leads the Nation in the production of hogs. Within many watersheds in Iowa, the number of animal feeding operations (AFOs), such as large-scale hog confinement facilities, has doubled in the past several years. A typical hog produces two to five times the waste as a human. Thus, the large number of facilities in some watersheds can produce as much untreated waste as a large city (100,000's to millions of people). There are concerns that large confinement facilities may have a negative impact on the water quality. AFOs may add to the overabundance of nutrients that are already introduced into the environment from chemical fertilizer, atmospheric deposition, soil mineralization, and municipal discharge. In addition, manure spills cause fish kills and introduce large loads of nitrogen and phosphorus directly into the waterways that drain to the Mississippi River. Excessive nutrients can cause water-quality problems such as excessive algal growth, taste and odor problems, health effects in humans, and have been linked to the phenomena called hypoxia (dissolved oxygen of less than 2 milligrams per liter) in the Gulf of Mexico.

The National Water Quality Assessment Program collected water-quality samples monthly from 1996 to 1998 at twelve locations in eastern Iowa. Four of the smaller watersheds were selected for comparison in areas where land-use practices are similar, but there are differences in the density of AFOs and the amount of estimated manure applied within the watershed. A Geographic Information System was used to delineate drainage basins, locations of large scale feeding operations, and manure inputs within each basin.

Concentration and yields of nutrients were compared between the sites using a Wilcoxon Rank sums test. There were statistical differences ($p < .05$) in concentrations and yields between some of the sites. Concentrations were greater in high-density AFO watersheds than low-density AFO watersheds for dissolved ammonia and organic nitrogen, total ammonia and organic nitrogen, and organic nitrogen. Nutrient yields for total nitrogen, organic nitrogen, and total phosphorus were statistically greater in watersheds with higher AFO densities. However, high-density AFO watersheds did not always have greater concentrations for total nitrogen, dissolved ammonia, nitrate, nitrite, dissolved phosphorus, total phosphorus, and dissolved orthophosphate than low-density AFO watersheds. Differences in physiography, agricultural practices (for example, amount and timing of manure and chemical fertilizer application), soil type, soil slope, and precipitation could be attributed to some of the differences. The data reflect a very complex system that requires long-term water-quality monitoring to determine if these differences in water quality are directly related to AFOs. Many of the AFOs have only been operating for a few years. More time may be required before their effects are reflected in the water quality of these basins.

---

[1]U.S. Geological Survey, Federal Bldg., Rm. 269, 400 South Clinton Street, Iowa City, IA 52240 (kdbecher@usgs.gov)

[2]U.S. Geological Survey, Federal Bldg., Rm. 269, 400 South Clinton Street, Iowa City, IA 52240 (kkakers@usgs.gov)

Agriculture and Bacterial Ground-Water Quality in Central Appalachian Karst

Douglas G. Boyer [1]

The impact on water quality by agricultural activity in karst terrain is an important consideration for resource management within the Appalachian Region. Karst areas comprise about 18 percent of the Region's land area. An estimated one-third of the Region's farms, cattle, and agricultural market value are on karst terrain. An eight-year study (1991-98) was conducted in a karst region in southeastern West Virginia to determine the impact of agriculture on ground-water quality. The primary agriculture was grass-fed beef with some animal feeding operations, which were primarily dairy.

Fecal-coliform densities were measured weekly in the resurgences of three karst basins possessing different degrees of agricultural intensity (79, 51, and 16% land use in agriculture). Fecal coliforms also were measured in a creek at sites upstream and downstream from the known resurgences from the most agriculturally intensive (79%) basin.

The fecal-coliform densities in the resurgences followed a pattern of peak densities in the summer and a dramatic decline in the fall, with a recovery in late winter prior to the introduction of new cattle. The timing of the recovery indicated that significant storage of fecal material had taken place, which was transported to the ground water when soil-water conditions permitted. For most of each year, soil-water effects appeared to have a greater bearing on the fecal-coliform densities than did the presence or absence of cattle. The data did not generally support a strong relation with percent land use in agriculture, which was attributed to the high variability in the data and to low soil moisture during periods of recession that inhibited the transport of fecal material to the ground water. The karst resurgence springs of the most intensively agricultural basin were contaminated with fecal bacteria. Fecal-bacteria concentrations were observed to significantly increase, in the receiving surface stream, from a point upstream of the resurgence springs to a point downstream of the resurgence springs.

Fecal-bacteria densities also were measured in cave streams draining two primary agricultural land-management areas. The first area was pasture serving a beef cow-calf operation. The second area was a dairy. Neither area had best-management practices in place for controlling animal wastes. Median fecal-coliform and fecal-streptococcus densities were highest in cave streams draining the dairy. Median fecal coliform densities in the dairy-impacted stream were greater than 4,000 colony forming units per 100 milliliters (CFU/100 ml) and the median fecal-coliform densities in the pasture-impacted streams were less than 10 CFU/100 ml. Median fecal-streptococcus densities in the same streams were greater than 2,000 CFU/100 ml and 32 CFU/100 ml, respectively. A second dairy, with best-management practices for control of animal and milkhouse waste, did not appear to be contributing significant amounts of fecal bacteria to the karst aquifer. It was concluded that agriculture was affecting bacterial densities in the karst aquifer. New management practices specifically designed to protect karst ground-water resources may be one way to protect the resource.

---

[1]U.S. Department of Agriculture, Agricultural Research Service, 1224 Airport Road, Beaver, WV 25813-9423 (dboyer@afsrc.ars.usda.gov)

Preliminary Observations of Nitrogen Speciation and Transport in Two Watersheds of the Chesapeake Bay Estuary

Owen P. Bricker[1], *Margaret M. Kennedy*[2], *and Peter Chirico*[3]

Sediment and water samples were collected from November 1997 through April 1999 from two watersheds, Popes Creek, Virginia, and the Pocomoke River, Maryland. The samples were collected to determine sites of nutrient storage and to evaluate nutrient concentrations that are associated with the sediments and dissolved materials being transported from watershed sources to the Chesapeake Bay. Popes Creek, which is located in Westmoreland County, Virginia, is a tributary to the Potomac River that flows into the Chesapeake Bay. The Pocomoke River, which is located on the eastern shore of Maryland, empties into the Chesapeake Bay through the Pocomoke Sound. The watershed of the Pocomoke River is 15 times larger than Popes Creek watershed and has tributaries that drain three counties in Maryland. Both watersheds lie in the Coastal Plain Physiographic Province. Since European settlement in the 1600's, agriculture has been the major land use in both watersheds. Popes Creek watershed, with very little agricultural activity at present, forms the basis for a reference in the comparison of the two watersheds. In the Pocomoke watershed, agricultural practices, such as ditching of fields and channelization of rivers and streams for improved drainage, are important factors in facilitating the transport of sediments and nutrients. Because of these practices, water that drains from agricultural fields effectively bypasses the riparian buffer zones where processing and uptake of nutrients takes place. In contrast to Popes Creek, poultry farming is extensive in the Pocomoke River watershed. In 1992, 182 million chickens were produced in three counties that are drained by the Pocomoke River. The intensive poultry farming, which produces nutrient-rich manure that is disposed of by spreading on fields in the watershed, has created a serious nutrient-enrichment problem in the river and in Pocomoke Sound. The spatial distribution of the concentrations of nitrogen species in sediment and in water in the two watersheds is displayed in a Geographic Information System (GIS) map format as an image coverage that overlies the ditches, river channels, and the geologic framework of the basins.

---

[1]U.S. Geological Survey, MS 432, 12201 Sunrise Valley Drive, Reston, VA 20192 (obricker@usgs.gov)

[2]U.S. Geological Survey, MS 432, 12201 Sunrise Valley Drive, Reston, VA 20192 (mkennedy@usgs.gov)

[3]U.S. Geological Survey, MS 926, 12201 Sunrise Valley Drive, Reston, VA 20192 (pchirico@usgs.gov)

High-Performance Liquid Chromatography/Electrospray Ionization–Mass Spectrometry Analysis of Agricultural and Human Health Pharmaceuticals in Surface and Ground Water

Jeffrey D. Cahill [1], *Edward T. Furlong* [2], *Stephen L. Werner*[3], *Mark R. Burkhardt*[4], *and Paul M. Gates*[5]

A method is being developed to identify and quantify agricultural and human health pharmaceuticals isolated from surface and ground water. This is an emerging water-quality issue because of the potential for deleterious sublethal effects of pharmaceuticals in water on humans, other animals, and the ecosystems they live in.

Nineteen pharmaceuticals were selected on the basis of predicted environmental loadings calculated from prescriptions and dosages and on the metabolic pathway of the parent pharmaceuticals in mammalian systems. The classes included analgesics, anti-inflammatories, antihypertensives, antianginals, antidepressants, antihyperlipidemics, antibiotics, antiulcerants, and anticoagulants. The pharmaceuticals were isolated from 1-liter water samples using resin-based solid-phase extraction. Extracts were analyzed by high-performance liquid chromatography using a 2-millimeter (mm) x 150-mm column containing a 3 micrometer particle size C-18 reversed phase. All 19 compounds were separated in less than 40 minutes by using a formate-modified, water-acetonitrile gradient. Electrospray ionization–mass spectrometry was used for qualitative identification and quantitation. Fragmentation conditions in the electrospray source were controlled so that three characteristic positive ions were produced for each compound. Selected-ion monitoring was used to maximize sensitivity.

Initial tests indicate that the 19 pharmaceuticals can be detected at individual concentrations as low as 50 to 100 nanograms per liter. Water samples being characterized by this method were collected nationwide from sites where the impact of pharmaceuticals was likely to be high, including sites downstream from wastewater treatment-plant discharge and confined agricultural feeding operations.

[1] U.S. Geological Survey, Denver Federal Center, Box 25046, MS 407, Denver, CO 80225-0046 (jdcahill@usgs.gov)

[2] U.S. Geological Survey, Denver Federal Center, Box 25046, MS 407, Denver, CO 80225-0046 (efurlong@usgs.gov)

[3] U.S. Geological Survey, Denver Federal Center, Box 25046, MS 407, Denver, CO 80225-0046 (slwerner@usgs.gov)

[4] U.S. Geological Survey, Denver Federal Center, Box 25046, MS 407, Denver, CO 80225-0046 (mrburk@usgs.gov)

[5] U.S. Geological Survey, Denver Federal Center, Box 25046, MS 407, Denver, CO 80225-0046 (pmgates@usgs.gov)

Odors, Nuisance, and the Right to Farm

Terence J. Centner[1]

Production agriculture has previously faced problems of odors. In the late 1960s, concern about new neighbors using nuisance law led agricultural-interest groups to advance anti-nuisance legislation. This legislation acquired the name of "right to farm" laws. While each state adopted individual legislation, the basic model sought to protect the existing investments of farmers in their agricultural operations. It sought this protection by incorporating a "coming to the nuisance" exception whereby persons moving to an offensive activity could not use nuisance law to seek judicial termination of the activity.

Right to farm laws gave a new life to many agricultural activities. While most of the laws were challenged, and provisions of the laws had to be interpreted by the judiciary, right to farm laws were fairly successful at discouraging nuisance lawsuits against farmers. At the same time, right to farm laws did not sanction offensive activities, negligent operations, or pollution. Because they only applied to nuisance actions, an incentive existed for farmers to be vigilant not to offend their neighbors or create problems. Zoning and local ordinances remained as vehicles for neighbors to seek redress against imprudent operations.

Recently, however, courts have been asked to view right to farm laws under constitutional takings jurisprudence. Current decisions and pending cases present some startling prospects--some state right to farm laws are unconstitutional. The Iowa Supreme Court found that a right to farm provision violated the Iowa Constitution and the Fifth Amendment of the U.S. Constitution. In the absence of compensation, the Iowa right to farm provision resulted in the taking of an easement of neighboring property without compensation.

A New York court is presented with a similar argument: does the N.Y. Agriculture and Markets law effect an unconstitutional taking of private property rights where it provides that agricultural practices will not constitute a private nuisance if the Commissioner of Agriculture has issued a Sound Agricultural Practice Opinion favorable to the farmer.

This paper will address these legal cases and the question of how AFOs might approach nuisance actions if courts adjudicate the demise of right to farm laws. Will AFO operators shop for the state where the right-to-farm protection has been upheld as not offending state and federal constitutions? Will nuisance law spur AFOs to adopt additional technology? Will AFOs be limited to locating in sparsely populated areas or selecting rural areas where their activities do not offend nuisance law? By examining right to farm laws, takings jurisprudence, and technology, the paper will seek answers to these questions.

---

[1]University of Georgia, College of Agricultural and Environmental Sciences, 301 Conner Hall, Athens, GA 30602-7509 (tcentner@agecon.uga.edu)

Ground-Water Quality at 94 Dairies in New Mexico

Clay Chesney[1]

In July 1998 two staff members from the Dallas Office of the U.S. Environmental Protection Agency (EPA) visited the Ground Water Quality Bureau of the New Mexico Environment Department and collected ground-water quality information at 94 dairies permitted by the State. This data-collection effort was part of a larger project to assess the ground-water-quality impacts of animal feeding operations in the five-State area comprising EPA Region 6.

New Mexico requires operators to monitor and report ground-water quality at dairy operations in the State, thus offering a unique opportunity to access a large data base suitable for statistical analysis.

Where available, information collected consisted of dairy location, depth to ground water, locations of monitor wells and the most recent four quarters of water-quality information on nitrate/nitrite and Kjeldahl nitrogen for ground water and waste lagoons. The number of monitoring wells at individual dairies range from 1 to 11. Site maps of all permitted dairies in the State were provided by the Bureau.

The dairies are concentrated in five areas; three of these are over river alluvium (middle Rio Grande, southern Rio Grande, Pecos River near Roswell), and two areas are on the eastern side of the State over the Ogallala aquifer. The alluvial environments are characterized by shallow ground water with strong temporal variations in flow direction and an abundance of highly permeable coarse-grained sediments. Ground water in the Ogallala aquifer typically occurs at greater depths and is generally considered less vulnerable.

The statistics of most interest for ground-water quality are median nitrate concentration and the percent of samples exceeding the maximum contaminant level (MCL) for nitrate as established by EPA under its public water-supply program. Analyses of 1,031 nitrate samples from the 94 New Mexico dairies showed the following:

- Median nitrate concentration for all samples was 4.4 milligrams per liter (mg/L).
- Thirty-six percent of dairies reported nitrate concentrations above the MCL of 10 mg/L.
- Monitoring wells located near the upgradient (with respect to ground water) boundary of the property exceeded the nitrate MCL at 20% of dairies having such wells (7 of 35). Cumulative effects caused by clustering of dairies in small areas are at least partly responsible for the high nitrate concentrations entering the individual sites.
- Samples from wells downgradient from waste lagoons suggest that these structures are typically involved in the most severe cases of contamination (59% of samples with nitrate-nitrogen above 100 mg/l are downgradient from lagoons).
- Samples from areas where liquid wastes are land applied had a high median nitrate concentration (8.3 mg/l) and a high percentage of values above the MCL (42% of the 36 dairies where ground water is monitored at land-application sites show nitrate above the MCL for those sites).
- Ground water from wells in barn areas and near runoff ponds had relatively low median nitrate concentrations, but wells downgradient from stock pens had very high nitrate levels (median of 18 mg/l with 7 of the 12 sites exceeding the MCL)

There appears to be a strong correlation between depth to ground water and nitrate concentration at the dairies, with few high nitrate concentrations where the water table is over 100-feet deep.

[1]U.S. Environmental Protection Agency, 1445 Ross Avenue, Suite 1200, Dallas, TX 75202-2733 (chesney.claybourne@epa.gov)

Distribution and Fate of Nitrate in Shallow Ground Water of Citrus Farming Areas, Indian River, Martin, and St. Lucie Counties, Florida

Christy A. Crandall[1]

The surficial aquifer system beneath citrus farming areas in Indian River, Martin, and St. Lucie Counties, Florida was investigated to detect impacts of citrus agriculture on shallow ground-water quality. Six citrus grove sites and one reference site were selected based on representative agricultural practices, soils, and tree age and health. Water-quality samples were collected and analyzed and water-level data were measured from 1996 through 1998. Elevated chloride and dissolved solid concentrations (indicators of agricultural influence) were found in ground water from citrus sites. The median chloride and dissolved-solids concentration in samples from citrus sites was 130 milligrams per liter (mg/L) and 796 mg/L, respectively. Median chloride and dissolved-solids concentrations in samples from the reference site were 23 mg/L and 171 mg/L. Nitrate concentrations in ground water exceeded the maximum contaminant level (MCL) for nitrate as established by the U.S. Environmental Protection Agency in only five percent of samples. These exceedances came from wells with depths of 10 feet or less at citrus sites and mostly from samples collected during or immediately following heavy fertilizer application. Samples from deeper wells contained little or no nitrate.

Conditions in the aquifer indicate that denitrification was primarily responsible for the reduction of nitrate in ground water. Organic carbon and iron concentrations (medians of 35 mg/L and 2.1 mg/L, respectively) were high, and dissolved-oxygen concentrations were low (generally less than 0.9 mg/L). Ground water from wells 10 to 15 feet in depth was enriched in $\delta^{15}N$ (median 25.5 per mil) indicating that fractionation occurred as a result of denitrification. Fertilizer samples had a median $\delta^{15}N$ of 3.0 per mil. Excess nitrogen gas (produced during denitrification) was extracted from ground water in wells 10 to 25 feet in depth; concentrations ranged from 1.7 to 8.3 mg/L.

---

[1]U.S. Geological Survey, 227 N. Bronough Street, Tallahassee, FL 32301 (crandall@usgs.gov)

Impacts of Animal Feeding Operations on Wildlife Health

Lynn H. Creekmore[1], *Mark J. Wolcott*[2], *and Mike D. Samuel*[3]

According to recent estimates, there are more than 450,000 Animal Feeding Operations (AFO's) located throughout the United States. More than 6,600 of these operations have greater than 1,000 animals and are classified as Concentrated Animal Feeding Operations (CAFO's). The number of new CAFO's has increased dramatically and many are located in the western United States. Because water resources are usually limited, the waste storage-lagoons used by many CAFO's attract a number of wildlife species, including migratory birds. Inadequate or poor waste management resulting in runoff, spills, or discharges and land application of waste from these facilities has the potential to impact wetlands and waterways that serve as important wildlife habitat. As a result, CAFO's may facilitate direct and indirect wildlife-health impacts by providing potential sources of disease agents or by providing suitable environments for the transmission and occurrence of disease in wildlife. Diseases and agents of concern for migratory birds and other wildlife species include Salmonellosis (*Salmonella* spp.), avian cholera (*Pasteurella multocida*), avian botulism (*Clostridium botulinum*), algal biotoxins, and other diseases. However, other than reported fish kills, the possibility that CAFO's cause wildlife mortality or negatively affect wildlife health is largely speculative. In addition, changes in waste-management operations that can reduce potential health risks to wildlife have not been adequately studied. The National Wildlife Health Center has the specific knowledge, capabilities, and expertise in toxicology, microbiology, virology, parasitology, and wildlife-health evaluation to play a lead role in determining health risks to wildlife species that use CAFO lagoons or adjacent lands and wetlands and in developing waste-management practices to reduce potential risks.

---

[1]U.S. Geological Survey, 6006 Schroeder Road, Madison, WI 53711-6223 (lynn_creekmore@usgs.gov)

[2]U.S. Geological Survey, 6006 Schroeder Road, Madison, WI 53711-6223 (mark_wolcott@usgs.gov)

[3]U.S. Geological Survey, 6006 Schroeder Road, Madison, WI 53711-6223 (michael_samuel@usgs.gov)

Ground-Water Protection and Manure Management

Matthew Culp[1]

Confinement livestock-production practices in Iowa produce large volumes of manure. The manure is stored in large earthen lagoons or basins for treatment or containment prior to disposal. Animal confinement owner/operators are required to submit a Manure Management Plan to the Iowa Department of Natural Resources (DNR). These plans describe method(s) for manure disposal. The most common method of manure disposal proposed is to apply it on agricultural land as a nutrient resource. The concentration of livestock, related waste, and land application of manure has increased concern for ground-water protection from chemicals and pathogens found in animal manure. Specific concerns include seepage of manure-derived contaminants from lagoons and basins in vulnerable ground-water areas. To evaluate the potential for ground-water contamination, the Iowa Geological Survey Bureau conducts site assessments of proposed lagoon, basin, or manure-application areas.

A vital tool used by the Iowa Geological Survey Bureau in conducting an assessment is the application of Geographic Information System (GIS) technology. The GIS contains a wide range of geologic and cultural data (called themes), which can be layered together in map form to examine a particular area or site. These data themes can be easily retrieved from computerized databases and shown on the computer screen to allow for comparison and interpretation of the geographic features and hydrogeologic conditions of any location. Being able to bring together the most accurate, up-to-date information available from numerous sources of data is a state-of-the-art tool that is very efficient and useful in assisting the geologist to evaluate a site's potential for ground-water contamination.

---

[1]Iowa Department of Natural Resources, Geological Survey Bureau, Henry Wallace Building, East 9th and Grand, Des Moines, IA 50319-0034 (mculp@max.state.ia.us)

Microbiological Quality of Public-Water Supplies in the Ozark Plateaus Aquifer System, Missouri

Jerri V. Davis[1]

Missouri is widely dependent on ground water as a source of drinking water for public-water systems. Historically, water from the deep bedrock aquifers in the Ozark Plateaus generally has been free from total and fecal coliform bacterial contamination. Little is known, however, about viral contamination and its relation to the bacterial characteristics of the ground water in the Ozark Plateaus. The Ozark Plateaus aquifer system is characterized as a carbonate system with numerous karst features throughout. The most important source of water for public supplies is the Ozark aquifer, both where it is unconfined and where it is confined by the Ozark confining unit and Springfield Plateau aquifer in southwestern Missouri.

The U.S. Geological Survey, in cooperation with the Missouri Department of Natural Resources, sampled 109 public-water-supply wells in water year 1997 and again in water year 1998 to characterize the microbiological quality of ground water in the Ozark Plateaus aquifer system. Samples from each well were analyzed for the following microbiological organisms—total human enteric viruses, male-specific and somatic coliphage, and fecal indicator bacteria (fecal coliform, *Escherichia coli*, and fecal streptococcus).

The data indicate that microbiological contamination of public-water supplies in the Ozark Plateaus is not widespread. Of the 109 wells sampled in water year 1997, 86 (about 79 percent) showed no presence of microbiological contamination. Human enteric viruses were present in samples collected from 11 of the 109 wells at concentrations ranging from 1.0 to 9.3 most probable number per 100 liters [confirmation of these results currently is (August 1999) underway]. Coliphage were present in samples collected from 11 wells at concentrations ranging from 38 to 2,600 plaque-forming units per 100 liters, and fecal indicator bacteria were detected in three wells at a concentration of 1 colony per 100 milliliters. Coliphage and human enteric viruses were present in two wells. Of the 109 wells sampled in water year 1998, 98 (about 90 percent) showed no presence of microbiological contamination. Coliphage were present in three wells, including one that was fecal-indicator-bacteria positive in water year 1997, at concentrations ranging from 41 to 78 plaque forming units per 100 liters. Fecal indicator bacteria were present in eight wells at concentrations ranging from 15 to 50 colonies per 100 milliliters. Coliphage and fecal indicator bacteria were not detected in the same well.

Results varied considerably between the first and second times of sampling, and no apparent correlation exists between the presence of enteric viruses and coliphage or indicator bacteria. Most of the virus and coliphage detections were outside the area with the most mature karst features. The wells mostly were located where the Ozark aquifer is confined or where the Ozark aquifer is unconfined and karst features are not well developed. The locations generally correlated with the areas that have the most intense agricultural land use, have the largest population, or had a population increase of greater than 10 percent from 1990 to 1997.

---

[1]U.S. Geological Survey, 1400 Independence Road, Rolla, MO 65401 (jdavis@usgs.gov)

A Risk-Based Approach to Phosphorus Management on Manured and Non-Manured Soils

Jessica G. Davis[1] *and Reagan M. Waskom*[2]

Eutrophication of surface waters often is related to phosphorus (P) runoff from agricultural fields. We evaluated P runoff from 17 furrow-irrigated fields in three different watersheds in Colorado in order to to examine the relationship between soil test P and P forms in runoff, to evaluate the use of the P Index for furrow-irrigated fields, and to determine the impact of manure application on P runoff potential. Soil test P (STP) from shallow samples (0-1 inch) taken from the furrow only was significantly correlated to ortho-phosphate, total soluble P, and bioavailable P concentrations in runoff. The P Index was not significantly correlated to any form of P measured in the runoff. However, the length of irrigation run (not included in the P Index) and the Irrigation Erosion factor from the P Index can be used to predict bioavailable P (r^2=0.81). Manured fields tended to have higher concentrations of ortho-phosphate, total soluble P, and bioavailable P in runoff than non-manured fields; however, the soluble organic P concentration was significantly higher in runoff from non-manured fields than from manured fields. STP was highly significantly correlated (r=0.85) with the P Index factor, Manure Application Rate (MAR).

---

[1]Colorado State University, Soil and Crop Sciences Department, Fort Collins, CO (jgdavis@lamar.colostate.edu)

[2]Colorado State University, Soil and Crop Sciences Department, Fort Collins, CO (rwaskom@agsci.colostate.edu)

Nitrogen, Sulfate, Chloride, and Manganese in Ground Water in the Alluvial Deposits of the South Platte River Valley near Greeley, Weld County, Colorado

Neville G. Gaggiani[1]

Ground water is used extensively for agriculture along the South Platte River in the study area, which is about 10 miles east of Greeley and about 50 miles northeast of Denver, Colorado. Significant changes in the reuse of water may result from use and reuse of water from the stream-aquifer system for irrigated crops, extensive use of crops and poultry farms. To help water users and managers better understand the effects of land use on ground-water resources, this report presents data on nitrite plus nitrate, sulfate, chloride, and manganese concentrations, which are good indicators of the water quality, and a brief description of the geology and hydrology of the study area.

---

[1]U.S. Geological Survey, Bldg. 2-85, Rocky Mountain Arsenal, Box 15, Commerce City, CO 80022-1748 (gaggiani@usgs.gov)

Abundance, Dissemination, and Diversity of Escherichia Coli in a Watershed in Northern Michigan

Sheridan K. Haack[1], *Jeffrey S. Wilson*[2], *Sarah M. Woodhams*[3], *David T. Long*[4], *Bryan C.Pijanowski*[5], *David F. Boutt*[6], *and David W. Hyndman*[7]

Contamination of recreational waters with disease-causing microorganisms is a significant, but poorly understood, environmental problem. Effective management of water resources for recreational quality requires improved understanding of the delivery and dissemination of bacteria. An interdisciplinary study, being conducted by a collaboration between the U.S. Geological Survey and Michigan State University, addresses patterns of delivery and dissemination of *Escherichia coli,* a representative enteric bacterium and an indicator of fecal contamination, to surface and ground water in a watershed in northern Michigan. To date, 234 *E. coli* isolates have been collected on three sampling dates (September 1997, May 1998, and October 1998) from 25 surface-water sites within the watershed. Ground water (28 wells) contained no *E. coli*. Isolates have been characterized by DNA fingerprints (rep-PCR profiles), and are being further characterized by patterns of resistance to the antibiotics streptomycin, tetracycline and ampicillin. At each site and date, 15 common water-chemistry parameters (for example, nutrients, major ions, dissolved oxygen) were evaluated. At selected sites and dates, indicator contaminants, such as fecal sterols, caffeine, human drugs, hormones, antibiotics and selected pesticides, have been analyzed. All sites have been mapped and characterized with respect to land-use patterns and other environmental and socioeconomic features using a geographic information system. Preliminary results suggest that on the September and October sampling dates, *E. coli* abundance and rep-PCR patterns were related to the percentage of urban land use at a site as well as to concentrations of chloride, magnesium, and nitrate. These patterns did not occur in May. *E. coli* rep-PCR profiles were very diverse in this watershed, indicating multiple, diffuse sources over short-flow paths and variation in source from day to day. Our results have significant implications for the design of monitoring programs, for modeling of bacterial contamination of recreational waters, and for understanding how to manage watersheds for bacteriological water quality. Models of bacterial contamination of recreational waters that use point sources and in-stream die-off to account for bacterial numbers would not accurately describe our observations. Our data indicate that management of watersheds for bacteriological water quality may require more information than is typically obtained in monitoring programs that simply determine bacterial numbers. Finally, our isolate characterizations provide insight into the genotypic and phenotypic diversity of environmentally-derived *E. coli* and reveal challenges that will be encountered in programs designed to detect specific pathogenic bacteria in recreational waters.

---

[1]U.S. Geological Survey, 6520 Mercantile Way, Lansing, MI 48911 (skhaack@usgs.gov)

[2]U.S. Geological Survey, 6520 Mercantile Way, Lansing, MI 48911 (jswilson@usgs.gov)

[3]Michigan State University, East Lansing, MI 48824

[4]Michigan State University, 236B Natural Science, East Lansing, MI 48824 (long@msu.edu)

[5]Michigan State University, 103 Natural Science, East Lansing, MI 48824 (pijanows@msu.edu)

[6]Michigan State University, East Lansing, MI 48824 (bouttdav@msu.edu)

[7]Michigan State University, 111 Natural Science, East Lansing, MI 48824 (hyndman@msu.edu)

Use of a Hydrogeologic Framework to Examine the Effects of Agricultural Fertilizers and Manure Applications on Nutrients in Shallow Ground Water of the Mid-Atlantic Coastal Plain

Tracy Connell Hancock [1], *Scott W. Ator*[2], *Sarah K. Kelley*[3], *and Judith M. Denver*[4]

The spatial distribution of nutrients in shallow ground water of the Mid-Atlantic Coastal Plain and processes that control this distribution are being evaluated within the context of a surficial hydrogeologic framework and other landscape variables. The newly developed framework provides a more detailed understanding of the surficial hydrogeology in this area than was previously available. In the Mid-Atlantic Coastal Plain, agriculture accounts for 29 percent of the land use. Confined animal feedlot operations (CAFOs), including poultry and swine, are particularly prevalent in the Delmarva Peninsula and in North Carolina, respectively. Agricultural practices involving the application of inorganic fertilizers and animal wastes from CAFOs can have major effects on the water quality in the surficial aquifer system. For instance, application of manure and fertilizers, which adds nutrients to the soil, can lead to increases in the concentration of nutrients in shallow ground water. In previous ground-water studies of the Delmarva Peninsula and the Mid-Atlantic region, nutrient concentrations in ground water were found to be higher beneath agricultural areas than beneath other land uses.

The vulnerability of ground water to nutrient contamination is controlled by a number of factors such as geology, soil type, hydrology, and land use. We are conducting a regional synthesis of existing ground-water data from the Mid-Atlantic Coastal Plain as part of the National Water Quality Assessment (NAWQA) Program. The data will be analyzed in the context of a regional hydrogeologic framework that was developed to define areas of the Coastal Plain where the occurrence and movement of chemicals into the shallow ground water and streams are controlled by a relatively consistent set of natural factors. In our study, we will describe nutrient concentrations and their mobility in the shallow ground water, analyze spatial patterns in regional nutrient data, and compare these spatial patterns to fertilizer and manure application data for particular areas of the framework.

---

[1]U.S. Geological Survey, 1730 E. Parham Road, Richmond, VA 23228 (thancock@usgs.gov)
[2]U.S. Geological Survey, 8987 Yellow Brick Road, Baltimore, MD 21237 (swator@usgs.gov)
[3]U.S. Geological Survey, 8987 Yellow Brick Road, Baltimore, MD 21237 (skkelley@usgs.gov)
[4]U.S. Geological Survey, 1289 McD Drive, Dover, DE 19901 (jmdenver@usgs.gov)

Potential Exposure of the Nation's Waters to Animal Manure

Kerie J. Hitt[1]*, Barbara C. Ruddy*[2]*, and Jeffrey D. Stoner*[3]

The National Water-Quality Assessment Program (NAWQA) has studied the effects of agricultural and urban land use on the quality of the Nation's streams and ground water since 1991. Analysis has emphasized the presence and distribution of nutrients and pesticides derived primarily from anthropogenic nonpoint sources. Regional investigations of major river and aquifer systems, called Study Units, give perspective to emerging water-quality issues, such as the potential movement of nutrients from animal-feeding operations (AFO's) to nearby streams and shallow ground water (less than 80 feet deep). Analysis of data from the first 20 Study Units distributed across the Nation has demonstrated that nitrogen and phosphorus yields to streams and nitrate concentrations in shallow ground water generally increase with increased concentration of land applications of fertilizer and animal manure. The concentrations of nutrients in water also are related to local conditions of soils, geology, and hydrology. Census of Agriculture data on animal populations from the 1980s and 1990s were plotted by county on national maps to compare regional distributions and patterns of change over time. Nitrogen content in manure from different animals also was estimated and compared to the distribution of well-drained soils as an initial estimate of potential AFO effects on shallow ground-water quality.

Although AFO's were not specifically studied as sources of nutrients in water, some inferences about AFO effects in various regions can be made from the available data. In five Study Units in the eastern and the central United States where animal manure was substantially applied to the land, rankings of nutrient concentrations in streams and shallow ground water were excessive compared to the other Study Units. The general trend was high concentrations of nitrate in ground water where manure was applied as fertilizer and where the soils and the aquifer material, such as those comprised of permeable sand and gravel, karst limestone, or fractured rock, were susceptible to relatively rapid recharge. Compared to background conditions, elevated concentrations of nitrogen and phosphorus were detected in some streams near farmland where animal manure was applied. Areas of sloping, low-permeable soils were associated with some of the highest concentrations of nutrients in streams.

[1]U.S. Geological Survey, MS 413, 12201 Sunrise Valley Drive, Reston, VA 20192 (kjhitt@usgs.gov)

[2]U.S. Geological Survey, MS 415, Box 25046, Denver Federal Center, Denver, CO 80225-0046 (bcruddy@usgs.gov)

[3]U.S. Geological Survey, MS 415, Box 25046, Denver Federal Center, Denver, CO 80225-0046 (stoner@usgs.gov)

Regulating Intensive Livestock Operations in North Carolina

Sue Homewood[1]

On December 10, 1992, the North Carolina Environmental Management Commission adopted a rule modification (15A NCAC 2H .0217) to establish procedures for properly managing and reusing animal wastes from intensive livestock operations. The rule applies to new, expanding or existing feedlots with animal waste-management systems designed to serve more than or equal to the following animal populations: 100 head of cattle, 75 horses, 250 swine, 1,000 sheep, or 30,000 birds with a liquid-waste system. This rule requires all animal operations with these threshold numbers of animals to develop and implement a certified animal waste-management plan.

Since the adoption of this rule, North Carolina has become a leader in regulating intensive livestock operations. As the number of hogs in North Carolina rapidly increased to ten million, substantial legislation that continued to increase the regulatory requirements for intensive livestock operations was developed by the 1995, 1996, and 1997 North Carolina General Assemblies.

Existing intensive livestock operations currently are required to receive coverage under a general permit or receive an individual permit from the Department of Environment and Natural Resources (DENR). New and expanding operations must receive a permit prior to beginning any construction. The permits incorporate site-specific conditions that were developed and implemented as part of the facility's certified animal waste-management plan.

In addition to requiring a permit, all intensive livestock operations undergo yearly operation reviews by staff from the DENR (the Division of Soil and Water), as well as, yearly compliance inspections by DENR (the Division of Water Quality) staff. Facility owners and operators are required to keep extensive records of animal waste-management practices and operations and to make these records available to staff during annual reviews and inspections. DENR has been tracking the results of these two annual visits since they began in January 1997.

All intensive livestock operations are required to have a certified animal waste-management operator. These operators must attend a ten-hour training course, pass an exam, and pay an annual fee. In order to be able to renew their certification, an operator must attend six hours of approved continuing education courses over a three-year period.

The 1997 North Carolina General Assembly enacted House Bill 515 (an Act to Enact the Clean Water Responsibility and Environmentally Sound Policy Act), which established a moratorium on the construction or expansion of swine farms. The purpose of the moratorium was to allow counties time to develop local zoning ordinances, as well as to allow studies to be done as to the impact of swine operations on the environment and public health in North Carolina. In addition, the North Carolina Environmental Management Commission recently adopted air-quality regulations for intensive livestock operations.

Regulating intensive livestock operations has developed very rapidly in North Carolina. We are confident that time will show that the efforts made by the State in regulating animal waste-management operations have made a positive impact on our environment, public health, as well as the industry itself.

---

[1]North Carolina Department of Environment and Natural Resources, 1617 Mail Service Center, Raleigh, NC 27699-1617 (Sue_Homewood@h2o.enr.state.nc.us)

Ecological Effects of Antibiotics in Runoff from an Eastern Shore Tributary of the Chesapeake Bay

Jenefir Isbister[1], Thomas B. Huff[2], Nancy S. Simon[3], and Trinh Tu[4]

Manure containing dietary antibiotics from approximately 82 million chickens is used to fertilize the fields in the Pocomoke River Basin. The Pocomoke River is a tributary of the Chesapeake Bay, in the Delmarva Peninsula of Maryland. Runoff from agricultural fields on which the manure is applied affects the ecology of the Pocomoke River. The altered ecology has been suggested as a contributor to outbreaks of toxic microorganisms including *Pfiesteria picicida* resulting in large fish kills and human health problems. In this paper, we describe results of screening studies of microbial populations in Pocomoke River bed sediments and from the bed sediments of a reference basin, Popes Creek, Virginia. Popes Creek is a tributary of the Potomac River that empties into the Chesapeake Bay. In addition, we propose a comprehensive study to evaluate antibiotic resistance of microbial populations from the two watersheds.

Preliminary studies have demonstrated differences in microbial populations in the two watersheds. Screening studies suggest that antibiotic resistant microorganisms are present in Pocomoke River sediments. By comparison, microorganisms from Popes Creek sediments were sensitive to the antibiotics that were tested.

We propose a collaborative study between the U.S. Geological Survey and George Mason University in which the distribution of antibiotics originating in poultry feed is determined and the effect of this distribution on the microbial communities in the two watersheds is evaluated. Water and sediment samples will be extracted and analyzed using high performance liquid chromatography with ultraviolet diode array and integrated pulsed amperometric detectors for a broad spectrum of hydrophilic and hydrophobic antibiotics often included in poultry feed. Aerobic and anaerobic microbial communities from the two watersheds will be compared with respect to sensitivity and resistance to the antibiotics found in water and sediment samples.

Data collected from this study will assist researchers in targeting and monitoring key antibiotics in tributary watersheds of the Chesapeake Bay. The data also will help to determine the environmental fate of animal antibiotics with respect to their partitioning between aqueous and solid phases. A goal of this project is to assess the effects of antibiotics on microbial activity in an environmentally sensitive watershed.

---

[1]George Mason University, SRIF MSN 4D7, 4400 University Dr., Fairfax, VA 22030

[2]George Mason University, SRIF MSN 4D7, 4400 University Dr., Fairfax, VA 22030 (thuff@gmu.edu)

[3]U.S. Geological Survey, MS 432, 12201 Sunrise Valley Drive, Reston, VA 20192 (nssimon@usgs.gov)

[4]George Mason University, SRIF MSN 4D7, 4400 University Dr., Fairfax, VA 22030

National Association of State Departments of Agriculture (NASDA) CAFO Survey Results

Charles W. Ingram[1] and Jeffrey G. Anliker[2]

One of the major environmental challenges facing our country today is nonpoint source (NPS) pollution/runoff from agricultural lands, urban streets, construction activities, individual septic systems, parking lots, and other areas. Agriculture, in particular, has received considerable attention in recent years as State and Federal agencies have sought to increase water-quality-protection efforts. States are aggressively pursuing and expanding resource-conservation activities to minimize agricultural nonpoint source pollution. Significant environmental improvements have been achieved while enhancing agricultural competitiveness and farm profitability. Successful efforts have been obtained where the activities are voluntary, partnerships use a team approach, and specific needs of each area are met. All of this has occurred without legislation or regulation from the Federal level.

The Clean Water Act (CWA) and the National Pollution Discharge Elimination System of permits (NPDES) do not stand alone in protecting America's waters from NPS runoff from animal feeding operations. In particular, the State-led programs, when coupled with various Farm Bill, Clean Water Act, and Safe Drinking Water Act incentives and support, can provide significant and continuing opportunity for major environmental-quality protection. Federal water policies must recognize that the value of the State programs, if enhanced through Federal efforts, could provide a firm foundation for a sound national NPS policy, including addressing the runoff associated with animal agriculture.

States often have tackled environmental-quality issues before they reach national attention and federal efforts. Recently, the Environmental Protection Agency (EPA) and the U.S. Department of Agriculture (USDA) issued a final strategy to curb water pollution from animal feeding operations (AFOs). Further, almost all States are utilizing existing laws, regulations, strategies, and programs to address water quality concerns associated with animal-waste management. In many cases, States have effective programs for protecting water quality without the use of a permit program.

NASDA recently completed a survey of state programs and requirements for Concentrated Animal Feeding Operations (CAFOs). Our survey found that about one-half of the states presently require the development and implementation of a nutrient management plan for the application of manure to the land based on the application of nitrogen, phosphorus, or both, depending on the most limiting nutrient. In addition, over one-third of the States have statutes or requirements that are more stringent than current Federal regulations. This presentation will provide additional information on the results of the CAFO survey.

---

[1]National Association of State Departments of Agriculture, 1156 15th Street N.W., Suite 1020, Washington, DC 20005

[2] National Association of State Departments of Agriculture, 1156 15th Street N.W., Suite 1020, Washington, DC 20005 (jeff@nasda-hq.org)

Development of Comprehensive Nutrient Management Plans for Animal Feeding Operations

Thomas A. Iivari[1]

Over 1.4 million agricultural enterprises in the United States have livestock or poultry operations of more than 0.1 animal units associated with their farms or ranches. While the number of animals raised has increased, the number of livestock operations has declined by 25 percent since 1992 and is expected to continue to decline over the next 10 years as "economies of scale" encourage larger size animal feeding operations (AFOs). This continued expansion and concentration of confinement-type facilities often is generating more animal waste and organic by-products than can be applied to a producer's land in an environmentally sound manner. In addition, the implementation of phosphorus-based nutrient-management standards will require more land for manure application, accentuating the challenges for AFO operators with scarce land.

The goal of the President's Clean Water Action Plan and its associated joint U.S. Environmental Protection Agency/U.S. Department of Agriculture (EPA/USDA) Unified National Strategy for Animal Feeding Operations identifies a national expectation that all AFOs will develop and be implementing comprehensive nutrient management plans (CNMPs) by 2009. The USDA-Natural Resources Conservation Service (NRCS) has estimated that 298,500 AFOs will need a CNMP to be developed and implemented in order to protect America's waters.

A CNMP is an interdependent group of conservation practices and management activities that allow a producer to achieve reasonable production goals while ensuring his/her AFO has minimal potential to adversely impact water and air quality, public health, and related natural resources around the facility and off-site. The components of a CNMP may include the following: 1) inputs to animals/internal functions (for example, animal feed, enzymes, diet supplements); 2) outputs of animals, to include animal waste and waste-water collection, handling, storage and treatment, and dead animal disposal; 3) site and/or operation inventory and evaluation along with recommended site treatment; 4) land application; 5) record keeping or maintenance of records that document nutrient and other organic by-products utilized and/or transported off-site; and 6) utilizing manure and organic by-products to provide for environmentally safe uses such as power generation, pelletization, composting, or converting to high-value products. Land application will consider nutrient budgets or balances for all potential sources of nutrients, runoff control, erosion control, leaching and deep percolation, atmospheric emissions (for example, spray aerosols, odors, dust), salts, pathogens, and other environmental concerns as identified.

Conservation practices used in a CNMP are to meet NRCS technical conservation practice standards. If NRCS does not maintain a technical standard for a CNMP component, the component is to meet the standard of another entity recognized by NRCS, such as Cooperative Extension, Land Grant Universities, State agencies, or industry. A CNMP is comprehensive to the extent that it considers nutrients from all sources. The final selection of a site-specific CNMP component is the producer's decision based on technically sound and economically feasible alternatives offered. Through voluntary participation, the extent to which the landowner/operator chooses to address the various natural-resource concerns is their decision.

---

[1]U.S. Department of Agriculture, Natural Resource Conservation Service, 5601 Sunnyside Avenue, Beltsville, MD 20705-5473 (tiivari@usda.gov)

Hepatitis E Virus Antibody Prevalence Among Selected Populations in Iowa

Yuory V. Karetnyi[1], Mary J. R. Gilchrist[2], and Stanley J. Naides[3]

Hepatitus E Virus (HEV) causes an enteric infectious disease endemic in developing areas with hot climate. A case of endogenous HEV infection has been reported in the United States. Recently, HEV-like virus was isolated from swine in Iowa. Swine production is a major industry in Iowa with the potential for human exposure to swine in and around industrial and family farm operations. In order to determine whether individuals in Iowa are exposed to HEV, anti-HEV antibody prevalence in four selected Iowa populations was determined. Sera were collected from 204 patients with non-A, non-B, non-C hepatitis (non-A-C); 87 staff members of the Department of Natural Resources (DNR); 332 volunteer blood donors in 1989; and 111 volunteer blood donors in 1998. All sera were tested for anti-human HEV IgM and IgG by ELISA with confirmation of positivity by a peptide neutralization test. Both patients with non-A-C hepatitis (4.9%) and the healthy field workers from the Iowa DNR (5.7%) showed significantly higher prevalence of anti-HEV IgG antibodies compared to normal blood donor sera collected in 1998 ($p < 0.05$). None of the sera had circulating HEV detectable by reverse transcription polymerase chain reaction amplification. In conclusion, human HEV, or a HEV-like agent, is present in the Iowa geographical area. At-risk human populations with occupational exposure to wild animals and environmental sources of domestic animal wastes or with unexplained hepatitis have increased seroprevalence of HEV antibodies.

---

[1]Division of Rheumatology, Department of Internal Medicine, and the Helen C. Levitt Center for Viral Pathogenesis and Disease, University of Iowa; VA Medical Center; and the University Hygienic Laboratory, University of Iowa, Iowa City, IA 52242 (yuory-karetnyi@viowa.edu)

[2]Division of Rheumatology, Department of Internal Medicine, and the Helen C. Levitt Center for Viral Pathogenesis and Disease, University of Iowa; VA Medical Center; and the University Hygienic Laboratory, University of Iowa, Iowa City, IA 52242 (mary-gilchrist@viowa.edu)

[3]Division of Rheumatology, Department of Internal Medicine, and the Helen C. Levitt Center for Viral Pathogenesis and Disease, University of Iowa; VA Medical Center; and the University Hygienic Laboratory, University of Iowa, Iowa City, IA 52242 (SNAIDES@viowa.edu)

A Multi-Tracer Approach for Determining Sources of Nitrate Contamination of Ground Water and Springs, Lafayette County, Florida

Brian G. Katz[1], *Johnkarl F. Bohlke*[2], *and H. David Hornsby*[3]

Wastes from animal farming operations (milk and beef cows, poultry, and swine) can potentially contribute large quantities of nitrogen (N) to ground water in Lafayette County, a rural area in northern Florida and one of the leading producers of milk and broiler chickens in Florida. During 1955-95, N inputs estimated from animal wastes (not corrected for losses due to volatilization and waste-handling practices) accounted for 28 to 53 percent of the estimated total N inputs (1.4 to 4.6 million kilograms per year) from all sources of N (fertilizers; atmospheric deposition; wastes from cows, poultry, and swine; and septic tanks). A multi-tracer approach, which consisted of the analysis of spring-water and shallow ground-water samples for naturally occurring chemical and isotopic tracers ($\delta^{15}N$, $\delta^{18}O$, δD, $\delta^{13}C$, CFCs, tritium) was used to determine sources and chronology of nitrate contamination of ground water in Lafayette County and other parts of the Suwannee River Basin. Water samples from six springs in Lafayette County [flows greater than 280 liters per second (L/s)] had $\delta^{15}N$-NO_3 values ranging from 5.4 to 9.1 per mil, likely indicating a mixture of inorganic and organic sources of nitrogen. Nitrate-N concentrations in spring waters ranged from 1.7 to 5.5 milligrams per liter (mg/L). Springs integrate ground water from large parts of the aquifer and mixing of waters from various convergent flow paths is reflected by the separation in apparent ages determined from measured concentrations of CFC-11 and CFC-113. Estimated residence times for ground water discharging to springs range from 15 to 77 years, based on CFC concentrations and the use of different flow-system models. Increases in nitrate concentration in water samples from Troy Spring (flow greater than 2,800 L/s) during 1960-98 track the increase in estimated fertilizer N inputs through the early 1980's followed by the increase in estimated N inputs from animal wastes during the mid-1980's to 1998.

In contrast, water from wells in the Upper Floridan aquifer (sampled zones were 7-13 meters (m) and 26-32 m depth below land surface) had $\delta^{15}N$-NO_3 values of 10.2 to 12.8 per mil, indicating an organic source of N. Ground-water ages ranged from 8-16 years based on measured CFC-113 concentrations and a piston-flow model. Nitrate-N concentrations in ground water were 18-20 mg/L during low-flow conditions (July 1997) in the Suwannee River, but decreased to 10-13 mg/L after a period of prolonged rainfall (March 1998). Slightly elevated concentrations of N_2 gas indicate that denitrification reactions may account for some of the decrease in NO_3 concentrations during high-flow conditions. Future studies in this area would benefit from the analysis of animal pharmaceuticals and their metabolites in ground water in an attempt to discriminate among various animal-waste sources of nitrogen, which cannot be done using nitrogen-isotope data alone.

---

[1]U.S. Geological Survey, 227 N. Bronough Street, Tallahassee, FL 32301 (bkatz@usgs.gov)

[2]U.S. Geological Survey, MS 431, 12201 Sunrise Valley Drive, Reston, VA 20192 (jkbohlke@usgs.gov)

[3]Suwannee River Water Management District, 9225 County Road 49, Live Oak, FL 32060 (hornsby_d@srwmd.state.fl.us)

Integrated Approach for a Comprehensive Nutrient Management Plan at Pahrump Dairy, Nevada

Jay Lazarus[1], *Catherine D. Ratcliff*[2], and *Eric Goedhart*[3]

Pahrump Dairy is located in Pahrump, Nevada, approximately 45 miles northwest of Las Vegas. Pahrump Dairy opened in 1988 and operates continuously with 2,300 milking cows and 600 dry cows/calves on-site. Pahrump Dairy operates under a State of Nevada approved Ground Water Discharge Permit which requires a Comprehensive Nutrient Management Plan (CNMP). The CNMP includes: land application of blended wastewater for on-site crop production, calculation of nitrogen loading rates, ground-water-quality monitoring, soil chemistry and crop yield monitoring, and prevention of ponding and runoff. Pahrump Dairy generates 99,040 gallons of wastewater per day, which is blended with ground water for irrigation of 196 acres of seasonally rotated cropland. Averaged over the year, the nitrogen uptake rate of the crops (sordan and wheat) exceeds the nitrogen application rate [59,285 pounds per year (lbs/yr)]. Depth to water in four monitoring wells completed into the alluvial aquifer ranges from 35 to 50 feet, and ground-water quality (nitrate, chloride, total dissolved solids) has been monitored since 1995. Nitrate concentrations exceeding 7 milligrams per liter (mg/L) have been reported, and Pahrump Dairy installed a solids separator in March 1999 to prevent recurrence. Removal of wet manure by the separator should result in decreasing nitrate concentrations in ground water and should eliminate the potential for excess nitrogen loading. This integrated approach to nutrient management and monitoring can be adapted to regions with shallow alluvial aquifers and highly transmissive unconfined aquifers such as portions of the Ogallala aquifer of the Great Plains.

---

[1]Glorieta Geoscience, Inc., P.O. Box 5727, Santa Fe, NM 87502
[2]Glorieta Geoscience, Inc., P.O. Box 5727, Santa Fe, NM 87502
[3]Pahrump Dairy, P. O. Box 880, Pahrump, NV 89041

Methods of Assessing Microbial Contamination of Surface and Ground Waters by Animal Feeding Operations

Donna N. Myers[1]

Animal feeding operations have been recognized as potential major sources of nutrient, antibiotic, and microbial contamination to surface water and ground water. Management of animal wastes, however, has not included monitoring and assessment of microbial pollutants. The American Society for Microbiology has called for a national monitoring program to assess the status of the Nation's waters in relation to animal (and human) waste contamination. State and Federal monitoring programs have largely underassessed the status of microbial contamination of water because of the emphasis in recent years on chemical contamination. The lack of information from past monitoring programs on the microbial contamination of water can be remedied by future monitoring efforts. Available techniques and methods for sampling and analyzing bacterial, viral, and protozoan pathogens and their indicators need to be disseminated to water-quality professionals. This information can be used to help assess the status of the Nation's waters in relation to microbial contamination.

Recently developed methods for sampling and analysis of microbial contaminants are applicable to monitoring and assessing the effects of animal waste on streams, lakes, and ground water. Sampling and analysis of waterborne pathogens require special protocols for collection and analysis. These protocols include large volume samples and specialized sampling equipment. Waterborne pathogens often require sophisticated methods for separation from the water media, and detailed preservation, culture, and identification techniques. Conversely, improved and recently modified methods for sampling and analysis of microbial indicators are cost-effective and do not require specialized equipment or highly trained personnel.

Specialized sampling and analysis methods for ground water and surface water for microbial pathogens include 1-MDS filters for collection of enteric viruses and reverse transcriptase-polymerase chain reaction for analysis of enteric viruses. For *Cryptosporidium parvum,* examples of sample-collection methods and EPA method 1622 for analysis will be shown. New indicator methods will be reviewed including simultaneous determination of total coliform bacteria and *Escherichia coli* on MI media, methods for analysis of spore-forming and chlorine resistant indicators such as *Clostridium perfringens*, and methods of analysis of viral indicators --somatic coliphage and F-specific coliphage. These methods are readily applicable to the study of microbial contamination of natural waters by animal feeding operations.

---

[1]U. S. Geological Survey, 6480 Doubletree Avenue, Columbus, OH 43229-1111 (dnmyers@usgs.gov)

Dairy Impacts to Water Quality and Orange County Water District's Comprehensive Dairy Waste Management Strategy

Katherine A. O'Connor[1]

The Santa Ana River watershed has the highest density of dairy cows in the Nation, averaging 25-30 cows per acre. Currently, 270 dairies operate on 25,000 acres within the Chino Basin portion of the watershed, with over 336,000 animals. Although the number of dairies continues to decrease, the number of animals is increasing, and the resulting impact on water quality is enormous. In the Chino Basin, the nitrate-nitrogen levels and total dissolved solids in the ground water exceed State and Federal water-quality objectives. The accumulation of salts and nitrates released from manure stockpiles and runoff of dairy washwater degrades the quality of the Santa Ana River, which recharges the Orange County ground-water basin.

The Orange County Water District (OCWD) manages both the flows of the Santa Ana River and the ground-water basin it recharges, which supplies over 2 million residents with about 75% of their water. The impact of large-scale dairies on recharge water quality is a critical issue for OCWD in protecting Orange County's primary drinking water supply. Manure-laden discharges to surface water during storm events contain protozoan parasites such as C*ryptosporidium* and *Giardia*, and pose a potential threat to public health. Organic loading into surface waters significantly decreases dissolved oxygen levels and has resulted in massive fish kills in recharge basins, which erodes public confidence in the safety of water supplies. In addition, increased salts and nitrates in the water supply shifts costs to the public sector as the economic costs of salts and salt reduction measures are transferred to the water purveyors and consumers.

OCWD is proceeding with a comprehensive approach to reduce the impact of dairy wastes on the Orange County ground-water basin, which includes: 1) incentive program for manure management, 2) enforcement of existing laws and regulations, and 3) participation in research and source-water-protection programs:

1) OCWD developed the "Tipping Fee Reduction Demonstration Program" to remove salt from the watershed by encouraging co-composting and export of manure. OCWD provided $175,000 in incentives to lower the tipping fee at a local co-composting facility to increase the deliveries of manure to 150,000 tons, a reduction of 11,550 tons of salt. The benefits of salt reduction by direct manure removal ($15 per ton of salt) far exceed ground-water-desalting costs ($318 per ton of salt).

2) OCWD works with regulators for monitoring and enforcement of dairy-waste-management regulations to ensure compliance with State and Federal law. OCWD is assisting the U.S. Attorney's Office and U.S. Environmental Protection Agency on a multi-agency Dairy Task Force to prosecute illegal discharge and disposal practices to prevent further deterioration of water quality.

3) OCWD is actively engaged in educational outreach with the dairy industry on source-water-protection efforts. OCWD also is pursuing collaborative research projects into the impact of dairy waste on water quality and public health. Research issues include: management of salts, nutrients, and pathogens released from manure; impacts of discharges containing hormones and antibiotics; and the fate and transport of pollutants to ground-water basins.

[1]Orange County Water District, 10500 Ellis Avenue, P.O. Box 8300, Fountain Valley, CA 92728-3373 (koconnor@ocwd.com)

Quantity and Quality of Seepage from Two Earthen Basins Used to Store Livestock Waste in Southern Minnesota, 1997-98--Preliminary Results of Long-Term Study

James F. Ruhl[1]

Numerous earthen basins have been constructed in Minnesota for storage of livestock waste. Typically, these basins are excavated pits with above-grade, earth-walled embankments and compacted clay liners. Some have drain tile installed around them to prevent shallow ground and soil water to discharge into the basins. Environmental concerns associated with the waste include contamination of ground water by nitrogen compounds and pathogens.

The U.S. Geological Survey, in cooperation with the Minnesota Pollution Control Agency (MPCA), studied the quantity and quality of seepage from two earthen basins used to store livestock waste in southern Minnesota during their first year of operation. One basin (site A), located at a small dairy farm, holds a manure-silage mixture, milkhouse wastewater, and local runoff; the other basin (site B), located at a large hog farm, holds a manure-water mixture from a nearby gestation barn. Monitoring systems were installed below compacted clay liners in portions of the sidewalls and bottoms of the basins to determine the quantity and quality of the seepage.

Total seepage flow from the site A basin ranged from about 900 to 2,400 gallons per day (gal/d) except during April 1998 when the flow increased to about 4,200 gal/d. Seepage flow in areal units, which closely correlated with flow in gallons per day, ranged from about 0.07 to 0.28 inches per day (in/d), which exceeded the recommended maximum design rate of 0.018 in./d established by the MPCA. Seepage flow commonly was greater through the sidewalls than through the bottom.

Seepage from the site A basin (based on 11 samples each from the bottom and sidewall) had chloride concentrations of 220-350 milligrams per liter (mg/L); ammonium-N (nitrogen) concentrations of 2.40 mg/L or less (except for one concentration of 18.4 mg/L); nitrate-N concentrations of 5.24 mg/L or less; and organic-N concentrations of 6.97 mg/L or less. Ground water would be enriched in chloride and diluted in nitrogen compounds from mixing with basin seepage. Fecal coliform bacteria, although abundant in the basin wastewater, were present in very small amounts in the seepage.

Total seepage flow from the site B basin generally ranged from 400 to 2,200 gal/d except during 1-month and 3-month periods when the flow ranged from about 3,800 to 6,200 gal/d. Seepage flow in areal units ranged from about 0.025 to 0.43 in/d, and, as at the site A basin, exceeded the MPCA recommended maximum design rate of 0.018 in/d. Seepage flow in areal units generally correlated with the flow in gallons per day except through the sidewalls when the basin was unfilled. Except during the first three months of the study, seepage flow was greater through the sidewalls than through the bottom.

Seepage from the site B basin (based on 11 samples each from the bottom and sidewall) had chloride concentrations of 11 to 100 mg/L; ammonium-N concentrations of 2.58 mg/L or less; nitrate-N concentrations of 25.7 mg/L or less (except for one concentration of 146 mg/L); and organic-N concentrations of 0.920 mg/L or less. Although background ground-water quality indicated nitrate contamination, seepage from the basin was potentially an additional source of nitrate contamination of the ground water. Nitrate-N concentrations in the seepage exceeded the U.S. Environmental Protection Agency drinking water standard of 10 mg/L in 17 of 22 samples. Fecal coliform bacteria, as at the site A basin, were abundant in the basin wastewater but not in the seepage.

[1]U.S. Geological Survey, 2280 Woodale Drive, Mounds View, MN 55112 (ruhl@usgs.gov)

The Shaping of Law through Ten Years of Hog Production in Oklahoma

Karl M. Rysted[1]

Oklahoma is viewed as a microcosm of all States that have, or will have huge, industrial-style hog production facilities. The central problem examined is the state's experience of rapid social, economic and legal changes during the last ten years as a result of a huge increase in Confined Animal Feeding Operations (CAFOs).

Statistics of hog production in the State are examined. Oklahoma statutory agricultural law is examined as being inseparably intertwined with this huge increase in hog production. The discrepancy between appearance and reality in recent legislation is examined as it relates to actual production, particularly the role of State boards comprised of political appointees in enforcing the legislation. It is postulated that the legislation may be a "toothless tiger," which does more for the image of a governor seeking reelection, for example, than for solving the problems with CAFOs. To bring about significant change, the continued involvement of concerned citizens in many venues is proposed.

The role of litigation is examined, as the conflict between public and special interests escalates through time. As a last resort, appeals are seen as necessary to continue shaping the common law in this area, possibly forcing State boards to protect the public interest as mandated by statutory law.

---

[1]The Sierra Club, 106 W. Main, Moore, OK 73160 (karl.rysted@sierraclub.org)

Minnesota's Generic Environmental Impact Statement on Animal Agriculture

Susan K. Schmidt[1]

Laws of Minnesota 1998 directed the Minnesota Environmental Quality Board (EQB) to conduct a Generic Environmental Impact Statement (GEIS) on animal agriculture. The purpose of the GEIS is to provide State and local policy makers with: objective, balanced information regarding the economic, environmental, health and social concerns related to animal agriculture; and develop recommendations regarding future options for animal agriculture in the State. The GEIS will involve three broad phases over approximately 2 ½ - 3 years: scoping, study and analysis, and finalizing the GEIS. A 25 member Citizen Advisory Committee (CAC) representing all interests has been established by the EQB to provide advice on the scope and content of the GEIS.

The GEIS Scoping Document -- a study outline that is based on extensive public input – was adopted by the EQB in December 1998. The Scoping Document includes an explanation of the 12 economic, environmental, social, and health topics to be addressed in the GEIS.

The EQB recently initiated the second phase of the GEIS aimed at study and analysis of the 12 identified topics. The first step of this phase is an in-depth summary of existing research on these 12 study topics. The "literature summary" will be conducted under the direction of the EQB through a contract(s) with outside experts during April through August 1999. The EQB, working with the CAC, will use the results of the literature summary to address the questions outlined in the GEIS Scoping Document and to determine the need for additional, new research that might be needed on the identified topics. Additional research is expected to be conducted during 2000.

The EQB also will gather information on location, size, species, and number of feedlots in the state. This GEIS "inventory" work will be conducted under EQB direction with outside experts during 1999. Existing data sources will provide the basis for this inventory. The statewide information on feedlot location, size, species, and number will enable the EQB to look at feedlot location and concentration relative to other variables of interest to the GEIS, such as population, population density, land use, water resources, ground-water sensitivity, and land base.

The GEIS process and status will be shared with interested conference participants as an example of one State's effort to address the feedlot controversy.

---

[1]State of Minnesota, Environmental Quality Board, GEIS on Animal Agriculture, 658 Cedar Street, St. Paul, MN 55155 (susan.schmidt@mnplan.state.mn.us)

Contaminants and Related Effects in Fish from the Mississippi, Columbia, and Rio Grande Basins

Christopher J. Schmitt[1], *Timothy M. Bartish*[2], *Vicki S. Blazer*[3], *Donald E. Tillitt*[4], *Timothy S. Gross*[5], *Gail Dethloff*[6], *Nancy D. Denslow*[7], *Wade L. Bryant*[8], *and L. Rod DeWeese*[9]

The overall objectives of this project are to describe the occurrence and distribution of contaminants and their effects on fish at selected sites in the Mississippi River, Columbia River, and Rio Grande basins; to quantitatively evaluate the performance of aquatic methods used by the U.S. Geological Survey (USGS) Biomonitoring of Environmental Status and Trends (BEST) program; and to evaluate potential collaborations with the USGS National Stream Quality Accounting Network (NASQAN-II) and National Water Quality Assessment (NAWQA) programs. Fish were collected in 1995 at 46 sites in the Mississippi River basin (*n*=1,338); in 1997 at 16 sites in the Columbia River basin (*n*=560) and 10 sites in the Rio Grande basin (*n*=368); and in 1996 from a reference site in West Virginia (*n*=39). Sites were located at historic National Contaminant Biomonitoring Program stations in all three basins; at NASQAN-II sites in the Columbia and Rio Grande basins; and at NAWQA sites in the Mississippi Embayment and Eastern Iowa Basins study units within the Mississippi River basin. The primary species targeted at each site were common carp (*Cyprinus carpio*) and largemouth bass (*Micropterus salmoides*). Other species, mostly other black basses (*Micropterus* spp.), percids (*Stizostedion* spp.), salmonids, suckers (Catostomidae), and catfish (Ictaluridae) were collected as alternates, depending on habitat and location. Individual fish (about 40 per site) were analyzed for reproductive biomarkers (plasma vitellogenin and sex steroid hormones), histopathological alterations, macrophage aggregates, hepatic EROD activity, plasma lysozyme activity, and general fish health measures (organosomatic and ponderal indices, observations of grossly visible lesions, deformities, and parasites).

Organochlorine (pesticides and total PCB's) and elemental (heavy metals and metalloids) contaminant analyses and the H4IIE bioassay for dioxin-like activity were performed on fish samples composited by species and sex. DDT residues (mostly as *p,p'*-DDE) in fish remained sufficiently high to represent a hazard to sensitive species of fish-eating birds at sites in all three basins. Toxaphene residues also remained evident at sites in the lower Mississippi and Rio Grande basins. The combined results of organochlorine chemical, H4IIE bioassay, and biomarker analyses indicated the presence of other organic contaminants in the lower Mississippi valley. Cyclodiene pesticides (dieldrin, endrin, and chlordane) were present in many agricultural areas, especially in the Corn Belt. Concentrations of these pesticides also were elevated near Memphis, Tenn., where there is a point source. Selenium concentrations were sufficiently high to constitute a hazard to piscivorous fishes and wildlife at one site in the upper Arkansas River, where levels have been increasing for approximately 10 years, and at several sites in the central Rio Grande basin. Mercury concentrations were higher in the predator species than in bottom fish and were elevated at one site in the Rio Grande and two in the Columbia basins. In the Mississippi basin, the occurrence of vitellogenin in plasma and of ovarian cells in the testes of male fish from several sites, along with abnormal ratios of sex steroid hormones, suggest that fish from some sites are exposed to endocrine-modulating substances. Biomarker results for the Columbia and Rio Grande basins are still pending.

[1]U.S. Geological Survey, 4200 New Haven Road, Columbia, MO 65201 (christopher_schmitt@usgs.gov)

[2]U.S. Geological Survey, 4512 McMurray Avenue, Fort Collins, CO 80525-3400 (tim_bartish@usgs.gov)

[3]U.S. Geological Survey, 1700 Leetown road, Kearneysville, WV 25430 (vicki_blazer@usgs.gov)

[4]U.S. Geological Survey, 4200 New Haven Road, Columbia, MO 65201 (donald_tillitt@usgs.gov)

[5]U.S. Geological Survey, 7920 NW 71st Street, Gainesville, FL 32653 (tim_s_gross@usgs.gov)

[6]U.S. Geological Survey, 4200 New Haven Road, Columbia, MO 65201 (gail_dethloff@usgs.gov)

[7]University of Florida, P.O. Box 100156, Gainesville, FL 32611 (denslow@biotech.ufl.edu)

[8]U.S. Geological Survey, 3850 Holcomb Bridge Road, Suite 160, Norcross, GA 30092 (wbbryant@usgs.gov)

[9]U.S. Geological Survey, Box 25046, MS 406, Denver Federal Center, Denver, CO 80225-0046 (rdeweese@usgs.gov)

Phosphate Sorption by Base Metal Hydroxides Generated in the Neutralization of Acid Mine Drainage

P. L. Sibrell[1] and P. R. Adler[2]

Excess phosphorus (P) in runoff from animal production facilities can result in nutrification of watersheds with serious consequences for aquatic life and water quality. In this research, the metal hydroxide waste product generated in the neutralization of acid mine drainage (AMD) was tested for adsorption capacity of P as phosphate. Acid mine drainage is caused by the oxidation of sulfide minerals such as pyrite to form sulfuric acid. The acid dissolves metals present in the sulfide minerals and associated rock, such as iron, aluminum, and manganese. Acid mine drainage is widespread in the Appalachian region due to decades of coal-mining activities predating regulation of acid discharge. When AMD is treated by neutralization with alkaline substances such as limestone or lime, a precipitate or floc is formed, consisting mainly of base metal hydroxides and unreacted alkaline material. Disposal costs of the floc can be as much as one half of the total operating cost for a treatment facility. Therefore, the floc would be an economical and widely available source of material for P sequestration should adsorption densities prove adequate. The effects of AMD composition and choice of alkaline neutralizing substances on floc formation and P adsorption were investigated. The test results were consistent with adsorption of P rather than chemical precipitation. Freundlich adsorption isotherms showed loadings of 30 to 50 milligrams (mg) P per gram dry weight of the sludge in equilibrium with solutions containing 0.1 to 1 mg P per liter. These loadings are much greater than for most natural soils. Phosphate adsorption also occurred under anaerobic conditions, such as would be found for wastes submerged in ponds or lagoons. Longer-term soil bag tests are planned to confirm these promising initial results.

---

[1]U.S. Geological Survey 1700 Leetown Road, Kearneysville, WV 25430 (philip_sibrell@usgs.gov)

[2]U.S. Department of Agriculture, Agricultural Research Service, 45 Wiltshire Road, Kearneysville, WV 25430-9425 (padler@afrs.ars.usda.gov)

Delaware's Animal Agriculture: Its Role in Nonpoint Source Pollution and Options for the Future

J. Thomas Sims[1]

Delaware agriculture has been dominated by a large and geographically intense poultry industry for more than 20 years. Today, about 260,000,000 broiler chickens are produced annually in a state with about 225,000 hectares of cropland. More than one-half of this cropland is used for the production of soybeans, where land application of animal manures is not recommended. Research dating back to the 1970's has investigated the relationship between poultry manure management and water quality, particularly nitrate-N contamination of ground waters and eutrophication of fresh and estuarine waters by nitrogen (N) and phosphorus (P). The fundamental cause of the nutrient-management problems facing Delaware's animal agriculture today is that geographic intensification has resulted in large surpluses of N and P, with no options to land application to agricultural crop land. A second, non-trivial cause is the numerous difficulties in efficiently managing animal wastes as nutrient sources (for example, storage, handling, analysis of nutrient content, and timely applications). Together, these factors have resulted in nutrient accumulations in soils to excessive levels and nutrient losses to ground and surface waters and to the atmosphere.

Today, Delaware's poultry industry faces many challenges. The U.S. Department of Agriculture/U.S. Environmental Protection Agency (USDA-USEPA) Unified Strategy for Animal Feeding Operations contains recommendations and requirements that will affect the economics of poultry production by intensifying the requirements to protect the environment. Further, in 1997 Delaware entered into a total maximum daily load (TMDL) agreement with USEPA as a result of a lawsuit filed against USEPA by a consortium of environmental groups. In the TMDL agreement, the State of Delaware agreed to reduce N and P loads to surface waters by as much as 60-85%. State legislation has been passed in Maryland, Virginia, and Pennsylvania and is now under consideration in Delaware that directly affects nutrient use by poultry producers and also impacts the poultry integrating companies. Clearly, a proactive approach is needed to address the nutrient-management challenges faced by Delaware's poultry industry.

This paper first presents an historical review of the research conducted in Delaware since the 1970's on the relationship between poultry waste management and water quality. Understanding the nature of the N and P management problems faced by the poultry industry is critical to the development of solutions. Next, a summary of the options available to reduce nonpoint-source pollution by nutrients origination in animal agriculture is provided, along with an analysis of the pros and cons of each option. Finally, a systematic approach forward is proposed, one that will both sustain the profitability of animal agriculture and protect and improve water quality in Delaware.

---

[1]Delaware Water Resources Center, University of Delaware, Newark, DE 19717-1303 (jtsims@udel.edu)

Identification of Sources of Nitrate in Ground Water--A Feasibility Evaluation

Timothy B. Spruill[1]

Information is needed by State, county, and municipal water managers, as well as various industries, to determine (1) parties responsible for ground-water contamination and (2) where reduction and management efforts need to be focused to accomplish non-point-source management goals. Geochemical-isotopic indicators can be used to identify contamination sources. For example, N^{15} has been used to identify animal or fertilizer nitrogen contamination. However, N^{15} cannot always distinguish unique sources because of variability caused by fractionation of the isotope in the environment, particularly in areas where denitrification is taking place. In addition, the analysis is relatively expensive, so its use on a routine basis may not always be practical. A study is being conducted to determine if combinations of major ions (ionic concentrations or ratios of various ionic species), organic compounds, isotopes, and other chemical data exist as unique or multivariate indicators for sources of ground-water contamination. Can the source of the contaminated sample be determined from the chemical data alone?

Discriminant analysis and cluster analysis were applied to limited data collected from 20 sites in four source categories (commercial fertilizer, septic, chicken/fertilizer, and hog wastes) in summer and fall 1996. Preliminary results of the discriminant analysis indicate the following:

(1) Potassium may be useful in identifying hog-waste sources because potassium is elevated in hog wastes.

(2) The discriminant model correctly identified hog-waste-contaminated ground water, hog-lagoon water, and fertilizer-contaminated ground water. These samples were ionically unique.

While initial results were promising for some categories, the procedure produced inconclusive results in other waste categories. The chicken/fertilizer-contaminated ground-water samples were correctly placed in only 25% of the cases. Two of the four chicken/fertilizer category samples were placed in the septic-system category and one in the unknown category. One of the two septic-system cases was incorrectly placed in the chicken/fertilizer category. Initial results indicate a need to better distinguish between the chicken/fertilizer and septic-system categories. Other variables or ratios and greater sample sizes within each category could improve the discrimination power.

Five sources of nitrate-contaminated ground water currently are being evaluated--commercial fertilizer applied to crops, hog waste, chicken waste, human wastes, and commercial fertilizer applied to golf courses. Water samples will be collected and analyzed from 10 temporary wells per category. Potential indicators that are being investigated include N^{15} of nitrate, major ion concentrations, organic carbon, zinc, copper, and methylene blue active substances.

[1]U.S. Geological Survey, 3916 Sunset Ridge Road, Raleigh, NC 27607 (tspruill@usgs.gov)

Molecular Tracers of Organic-Matter Sources to Drinking-Water Supplies

Laurel J. Standley[1], *Louis A. Kaplan*[2], *and Darryl Smith*[3]

We investigated the utility of various compounds for use as molecular tracers of contaminant sources in drinking-water supplies. Contaminant sources included wastewater treatment plants (WWTP), agricultural/feedlot runoff, urban/suburban runoff, and nature. After analysis of source materials, we selected the following tracers: fecal steroids, laundry detergent fragrances, caffeine, nonylphenols, polycyclic aromatic hydrocarbons, *n*-alkanes, and the unresolved complex mixture (UCM). Results were then correlated with measures of land-use obtained through surveys of drinking-water utilities.

Water samples (4 liters) were extracted using C-18 disks. Tracers were quantified using GC/MS, with selected ion monitoring to improve sensitivity.

Tracers associated with WWTP effluent, including coprostanol, fragrances, and caffeine, correlated well with each other, as did groups of molecular tracers targeted for other sources. Tracers also correlated with land-use values associated with their target source. For example, WWTP molecular tracers correlated with variables such as wastewater discharge and combined-sewer overflows. Urban tracers, such as UCM, correlated with transportation and other urban measures. Agricultural tracers correlated with factors such as feedlot runoff and animal densities of cattle.

When the watersheds were ranked according to increasing urban and agricultural influence using their molecular tracers, the influence of natural sources decreased, as would be expected where anthropogenic activity is greater.

---

[1]Stroud Water Research Center, 970 Spencer Road, Avondale, PA 19311 (ljstandley@stroudcenter.org)

[2]Stroud Water Research Center, 970 Spencer Road, Avondale, PA 19311 (lakaplan@stroudcenter.org)

[3]South Central Connecticut Regional Water Authority, 90 Sargent Drive, New Haven, CT 06511-5966

Cycling of Sulfur in the Anoka Sand Plain Aquifer and Its Relation to Denitrification

Michele Tuttle[1], J.K. Böhlke[2], Richard Wanty[3], Geoff Delin[4], and Matthew Landon[5]

The fate and transport of agricultural nitrate is of major concern in the Midwest cornbelt, especially where farms are underlain by surficial glacial deposits. To better understand this problem, a multiscale study focused on an agricultural-management system and its impact on ground water. As part of this study, we investigated sources of dissolved sulfate, sulfate reduction, and pyrite oxidation coupled to nitrate reduction along a ground-water-flow path in the Anoka Sand Plain aquifer, Battle Brook drainage basin near Princeton, Minnesota. A sampling transect was designed to parallel the ground-water-flow path and a nitrate plume in the upper surficial aquifer. Ground-water samples were collected from single- and multi-level wells beneath the Management Systems Evaluation Area (MSEA) and from sites further downgradient in an adjoining wetland. Sediment samples were collected from two cores, one beneath the MSEA field and one beneath the wetland. In addition, water samples were collected from domestic wells and streams throughout the drainage basin to provide a regional geochemical datum.

This study identified high amounts of nitrate [up to 80 parts per million (ppm) NO_3] in domestic wells throughout the Battle Brook drainage basin. Most surface waters, however, are relatively uncontaminated. In oxygenated waters beneath the MSEA field, sulfate concentrations and $\delta^{34}S_{SO4}$ values versus depth are related linearly. Because the ground water is stratified, this relation likely reflects the evolution of meteoric recharge water (3 ppm SO_4 and $\delta^{34}S$ value of 8 per mil (‰) sourced from precipitation, fertilizer, and irrigation water) along the flow path. The deepest ground water has 15 ppm SO_4 and a $\delta^{34}S_{SO4}$ value of –3‰. A decrease in nitrate concentrations with depth (60 to 14 ppm NO_3), together with the increase in sulfate concentrations and decrease in $\delta^{34}S_{SO4}$ values, indicate that denitrification occurs along the flow path.

In waters beneath the oxygenated interval, in wetland samples below the nitrate plume, and in wetland samples from the well closest to Battle Brook, redox conditions are sufficiently anoxic (O_2 <1 ppm) to support sulfate reduction. With increasing depth, sulfate is progressively reduced with an isotope enrichment factor of –4.5‰ (estimate of $\Delta_{SO4-H2S}$). The calculated $\delta^{34}S$ value for the initial sulfate is –2.6‰, similar to that in deeper ground water.

In wetland sediment at the distal end of the nitrate plume, an active denitrification zone has been identified. Within this zone, NO_3 concentrations range from 14 to 55 ppm and are inversely related to dissolved SO_4 concentrations that are greater than 15 ppm (up to 80 ppm). The isotopic composition of the dissolved sulfate ranges from –8‰ to -14‰. Sediment in the denitrification zone contains between 0.17 and 0.60 wt% pyrite that similarly is depleted in ^{34}S ($\delta^{34}S$ -4‰ to –10‰). The pyrite occurs as <2 micro-meter (µm) euhedral crystals, 1-2 µm grains aggregated into framboids that are 10-20 µm across, and detrital grains up to 400 µm across. These data and their relations show that sedimentary pyrite, most likely that in the 1-2 µm grains, is an important electron donor in the denitrification process.

Our results and those from collaborative studies on the MSEA nitrate plume show that denitrification coupled to pyrite oxidation occurs along the ground-water flow path and in wetland sediments prior to ground water discharging to the surface. Pyrite oxidation releases sulfate to the ground water. In anoxic ground water, bacterially mediated sulfate reduction further modifies sulfate concentration and isotopic composition. Our understanding of sulfur cycling in the Anoka Sand Plain aquifer and how it relates to the fate and transport of agricultural nitrate in the Battle Brook drainage basin provide a foundation for studying denitrification in other glacial deposits having similar geochemical and hydrologic characteristics.

---

[1]U.S. Geological Survey, Box 25046, MS 973, Denver Federal Center, Denver CO 80225 (mtuttle@usgs.gov)
[2]U.S. Geological Survey, MS 431, 12201 Sunrise Valley Drive, Reston VA 20192 (jkbohlke@usgs.gov)
[3]U.S. Geological Survey, Box 25046, MS 973, Denver Federal Center, Denver CO 80225 (rwanty@usgs.gov)
[4]U.S. Geological Survey, 2280 Woodvale Drive, Mounds View, MN 55112 (delin@usgs.gov)
[5]U.S. Geological Survey, Room 406 Federal Building, 100 Centennial Mall North, Lincoln, NE 68508 (landon@usgs.gov)

Roxarsone in Natural Water Systems

R. L. Wershaw[1], J. R. Garbarino[2], and M. R. Burkhardt[3]

Organic arsenic compounds are extensively added to the feed of broiler chickens. The most commonly used arsenic compound is roxarsone (3-nitro-4-hydroxyphenylarsonic acid), which is fed to poultry to control coccidial intestinal parasites, thereby improving feed efficiency. Very little of the roxarsone is retained in the chicken meat (FDA limit is 0.5 parts per million in chicken muscle tissue). Most of the roxarsone is excreted unchanged; however, the degradation product, 3-amino-4-hydroxyphenylarsonic acid, has been detected in the urine of hens fed roxarsone. We estimate that approximately 10^6 kilograms (Kg) per year of roxarsone and its degradation products are introduced annually into the environment from the disposal of poultry litter spread onto agricultural fields near the chicken houses. This practice could result in localized arsenic pollution.

No studies have been conducted on the fate of roxarsone or the degradation pathways of the compound in soils and natural waters. However, it is possible to predict the types of degradation reactions that roxarsone could undergo by consideration of the environmental behavior of compounds that contain one or more of the same structural units as roxarsone. Three of the most likely reactions are listed in Table 1.

Table 1. Possible environmental reaction mechanisms of roxarsone

Reaction	Examples
Reduction of nitro group	Reduction of trinitrotoluene in soil to monoamines and diamines.
Oxidative aromatic ring fission	Enzymatic oxidative fission of lignin units to form aliphatic acids.
Rupture of C-As bond	Conversion of organoarsenicals to arsenate by ultraviolet irradiation.

Microbial biodegradation of aromatic compounds takes place in the following sequence: N- and O- demethylation, hydroxylation, and deamination followed by ring fission, chain shortening, and oxidative removal of substituents. Oxidative ring fission leads to the formation of carboxylic acid groups on the cleaved ends of the rings. If roxarsone were to undergo such a reaction sequence, arsonoalkyl acids would be produced. The arsonoalkyl acids could then undergo conversion to alkylarsines, which are stable under anaerobic conditions. Under aerobic conditions, methylarsines undergo rapid oxidation to AsO_4^{3-}. The degradation reactions outlined above indicate that 3-amino-4-hydroxyphenylarsonic acid, methylarsines, and AsO_4^{3-} are possible environmental-degradation products of roxarsone. In order to assess the environmental impact of introduction of large amounts of roxarsone into a watershed, the concentrations of each of these compounds must be measured in the soils, sediments, and natural waters of the watershed at different times during the hydrologic cycle.

The U.S. Geological Survey will develop separate analytical methods to measure roxarsone and its organic and inorganic degradation products in surface water, ground water, and soils. Inorganic arsenic species currently are determined by using ion chromatography to separate the species followed by hydride generation and inductively coupled plasma–mass spectrometric detection. Detection limits are 0.2 microgram per liter (µg/L) for arsenate and arsenite using a 100–microliter (µL) injection. Organoarsenic compounds, including roxarsone and 3-amino-4-hydroxyphenylarsonic acid, will be separated using reverse phase liquid chromatography and determined by electrospray mass spectrometry. We anticipate a detection limit for roxarsone of 50 nanograms per liter (ng/L) using a 50-µL injection. Surface- and ground-water samples will be processed in the field to separate the inorganic and organic species using a polymeric solid phase extraction cartridge. Organoarsenic compounds will be extracted from the cartridge with 0.2% trifluoracetic acid in acetone. Roxarsone and its metabolites will be extracted from soils using methylene chloride prior to analysis by electrospray mass spectrometry.

[1]U.S. Geological Survey, Box 25046, MS 408, Denver Federal Center, Denver, CO 80225-0046 (rwershaw@usgs.gov)
[2]U.S. Geological Survey, Box 25046, MS 407, Denver Federal Center, Denver, CO 80225-0046 (jrgarb@usgs.gov)
[3]U.S. Geological Survey, Box 25046, MS 407, Denver Federal Center, Denver, CO 80225-0046 (mrburk@usgs.gov)

Nitrous Oxide Emission from a Spray Field Fertilized with Liquid Lagoonal Swine Effluent in the Southeastern United States

Stephen C. Whalen[1], Rebecca L. Phillips[2], and Eric N. Fischer[3]

Contemporary agriculture is characterized by the intensive production of livestock in confined facilities and land application of stored waste as an organic fertilizer. Emission of nitrous oxide (N_2O) from receiving soils is an important, but poorly constrained term, in the atmospheric N_2O budget. In particular, there are few data for N_2O emissions from spray fields associated with industrial scale, swine-production facilities that have rapidly expanded in the southeastern United States. In an intensive, 24-day investigation over three spray cycles, we followed the time course for changes in N_2O emission and soil physicochemical variables in an agricultural field irrigated with liquid lagoonal swine effluent. The total-N [535 milligrams per liter (mg/L^{-1})] of the liquid waste was almost entirely NH_4^+-N (>90%) and thus had a low mineralization potential. Soil profiles for nitrification and denitrification indicated that >90% of potential activity was localized in the surface 20 centimeters (cm). Application of this liquid fertilizer to warm (19 to 28^{o}C) soils in a form that is both readily volatilized and immediately utilizeable by the endogenous N-cycling microbial community resulted in a sharp decline in soil NH_4^+-N and supported a rapid and short-lived (days) burst of nitrification, dentrification, and N_2O emission. Fluxes of nitrous oxide as nitrogen (N_2O-N) as high as 9,200 micrograms per gram dry weight of soil per hour ($\mu g\ g_{dw}^{-1}\ h^{-1}$) were observed shortly after fertilization, but emissions decreased to prefertilization levels within a few days. Poor correlations between N_2O efflux and soil physicochemical variables (temperature, moisture, NO_3^--N, NH_4^+-N) and fertilizer-loading rate point to the complexity of interacting factors affecting N_2O production and emission. Total fertilizer N applied and N_2O-N emitted were 29.7 grams per square meter (g/m^{-2}), and 395 milligrams per square meter (mg/m^{-2}), respectively. The fractional loss of applied N to N_2O (corrected for background emission) was 1.4%, in agreement with the mean of 1.25% reported for synthetic fertilizers. The direct effects of fertilizer application appear to be more immediate and short-lived for liquid swine waste than for manures and slurries that have a slower release of nitrogenous nutrients.

---

[1]University of North Carolina, Department of Environmental Science and Engineering, Chapel Hill, NC 27599-7400 (steve_whalen@unc.edu)

[2]University of North Carolina, Department of Environmental Science and Engineering, Chapel Hill, NC 27599-7400 (rebecca.phillips@sph.unc.edu)

[3]University of North Carolina, Department of Environmental Science and Engineering, Chapel Hill, NC 27599-7400 (efischer@email.unc.edu)

Evaluating the Cumulative Impacts from Animal Feeding Operations within Impaired Watersheds in Texas: A Regulatory Approach

Clifton F. Wise[1]

The State of Texas benefits from a thriving livestock and poultry production industry. The diverse geography and climate of Texas allows each industry to concentrate in regions suited to its production demands. Beef cattle feedlots and swine operations are located in the West Texas High Plains; the dairy industry has developed in Central Texas; while broiler and layer hen operations are concentrated in East Texas. However, the cumulative impacts of these facilities have resulted in water-quality impairments in certain watersheds in the State.

In 1998, Texas submitted a list of impaired water bodies to the U.S. Environmental Protection Agency (EPA) to meet the requirements of Section 303 (d) of the Clean Water Act. Through the National Pollutant Discharge Elimination System (NPDES), the EPA has subsequently proposed additional regulations to address concentrated animal feeding operations (CAFOs) located in these watersheds. Preliminary studies conducted by EPA have indicated that discharges from CAFOs occur frequently and have the potential to contribute to water-quality impairments.

Concurrently, the State of Texas has initiated its own studies to independently evaluate the potential water-quality impacts associated with CAFOs. Three studies are presented outlining the latest research initiated by the Texas Natural Resource Conservation Commission (TNRCC). The research presented includes (1) a study on the impacts of nonpoint-source pollution associated with dairies located in Central Texas; (2) a poultry operations study on the existing or potential adverse impacts on water quality in three East Texas watersheds; and (3) a study on the impacts from point-source discharges from feedlots and swine operations located along the Canadian River in the Texas High Plains.

Armed with the results of these on-going studies, the TNRCC has proposed new regulations to address the potential impacts to water quality in Texas. The new regulations include additional requirements for nutrient utilization planning to limit pollutant runoff from land-application practices, as well as additional training and education requirements for facilities located in impaired watersheds. Furthermore, the TNRCC is coordinating with stakeholders and local and state agencies in the development of a total maximum daily load evaluation to further identify cumulative impacts from CAFOs as well as other sources of pollutants. And with the recent delegation of the NPDES program to the State of Texas, the TNRCC has increased coordination with EPA to provide a comprehensive and multi-media regulatory approach to solving the environmental problems associated with animal feeding operations.

---

[1]Texas Natural Resource Conservation Commission, MC-158, P.O. Box 13087, Austin, TX 78711 (cwise@tnrcc.state.tx.us)

Forum Session:

Open Exchange Among Participants

FORUM SESSION: Open Exchange Among Participants

Wednesday, September 1, 1999
Moderator: L. Rod DeWeese - USGS
Facilitator: M. Elizabeth Daniel - USGS

An open forum was held at the close of the Nutrients Session to allow a free flow of information, questions, and discussion. Approximately 120 attendees participated in the 2-hour Forum Session. The forum did not restrict or program any topics of discussion, but five questions (listed below) were posed to meeting attendees. Responses to these questions and major points in the ensuing discussion are summarized below in italics. These comments express the opinion of the participant and do not represent a position of the U.S. Geological Survey.

1. What are the major scientific questions/topics lacking information that could significantly add to the overall understanding of the environmental implications of AFOs?

- **Wildlife and habitat health: environmental assessment**
  - *Characterization and measurement of the occurrence and magnitude of nutrient, pathogen, and pharmaceutical concentrations and their relation to AFOs and effects on wildlife (amphibian, fish, bird, mammalian) health and habitat viability.*
  - *Effects of specific AFO management practices (such as feed storage, feed amendments, and lagoons for waste storage) on the health and habits of migratory birds and other animal species.*
- **Manure and other animal-residuals management**
  - *Study of the efficacy and efficiency of various lagoon- and other AFO manure-management strategies and the potential risk of surface-water or ground-water contamination.*
  - *Research on use of solar or wind power for aerobic or other types of treatment of animal residuals.*
  - *Assessment of and research on handling animal carcasses.*
- **Pathogens and other microorganisms**
  - Environmental assessment – *Microbiological profiles of surface water and ground water receiving AFO wastes.*
  - Research – *Antibiotic resistance in pathogens associated with AFO solid/liquid manure in soil, air, and water bodies.*
  - Methods development – *Develop standardized methods for detection and monitoring of source, transport, and fate of microorganisms*.

- **Pharmaceuticals (antibiotics, hormones, endocrine disruptors)**
- Environmental assessment – *Occurrence, distribution, concentration, and loading of animal pharmaceuticals in streams, ground water, soil, and the atmosphere.*
- Research and methods development – *Analytical methods for identifying pharmaceuticals at environmental concentrations.*
- Methods development – *Standardize field methods for monitoring source, transport, and fate of animal pharmaceuticals.*

▪ **Nutrients and trace elements**
- Methods development – *Methods for standardizing the identification of nutrient/trace element sources to distinguish among land uses.*
- Research – *Export/transport fluxes and cycling processes of nutrients and trace elements from AFOs to streams, ground water, air, soil, and vegetation.*

▪ **Air quality**
- Methods research and development – *Scientific methods to characterize and quantify gaseous emissions from AFOs.*
- Environmental assessment – *Effects of gases and other emissions from AFOs on air quality and human and animal health.*

▪ **Integrated, multidiscipline site studies: environmental assessment**
- Holistic approach at multidiscipline sites – *Multidiscipline data collected at the same location can be used to understand contaminant transport processes that link biology, microbiology, hydrology, chemistry, geology, and the atmosphere.*
- Tools – *Development and application of new or existing tools to understand sources, sinks, and processes governing contaminant mobility, concentration, and toxicity: for example, use of isotope geochemistry, ribotyping (RNA and DNA) of microorganisms, analysis, computer models, organic and inorganic tracers.*
- Human health – *Incorporate in environmental studies the data-collection strategies needed to address human health issues.*
- Economics – *Economic data and analysis should be a component of environmental and human health studies.*

▪ **Pollution treatment and prevention: methods research and development**
- *Effluent control and treatment.*
- *Research and development of effective remediation programs for existing large-scale AFO-generated pollution of ground water and soils.*

2. Can you provide examples* of successful interagency (State and Federal) and government/ private collaborative efforts concerning AFOs?

- California:

  The California Dairy Quality Assurance Program (CDQAP) that trains dairymen in environmental stewardship was cooperatively developed by the California Department of Food and Agriculture, various State, Federal, and regional agencies, and the University of California-Davis.

- Florida:

  The Florida Department of Environmental Protection and the USGS have worked together to identify the potential for environmental degradation from Florida's dairy, poultry, and pig industries.

* Although these were the only examples described in the open Forum Session, several other examples were mentioned in the course of the meeting, citing collaboration with university researchers and among agencies such as the USGS, Centers for Disease Control and Prevention (CDC), U.S. Environmental Protection Agency (USEPA), various agencies within the U.S. Department of Agriculture (USDA), various State environmental and health and natural resources departments, and the U.S. Fish and Wildlife Service (FWS), National Park Service (NPS), and National Forest Service (NFS).

3. What do you see as inhibiting collaborative efforts on AFOs?

- **Communication issues**
  - *Poor communication among scientists doing similar work.*
  - *Lack of networking to include different areas of expertise.*
  - *Lack of awareness of expertise within and among agencies.*
  - *AFO operators tend to mistrust government and have a perception that pro-environment agendas necessarily result in anti-business regulation.*
  - *Agricultural trade groups fear government intervention and environmental controls. The Agriculture/Dairy industry, for example, has enormous economic and political clout that can target scientific efforts if such efforts have not been adequately explained.*
  - *Negative attitudes/mistrust/misunderstanding among industry, the public, and government agencies is prevalent and problematic. Outreach and education efforts are inadequate.*
  - *The USEPA Clean Water Act language requiring "no discharge" is inhibiting innovative solutions. The USEPA should work with the agricultural industry when drafting sections of the Clean Water Action Plan (CWAP).*
- **Lack of funding**
  - *Funding barriers exist across agency/institution lines.*
  - *Competition for money among researchers both in and out of government.*
  - *Restrictions on funds by the USEPA and by State regulations.*
  - *More information and education is needed on the real and complete economic costs of AFOs.*

4. What changes or improvements do you recommend to increase collaborative partnerships among government and non-government interests in AFOs?

- *Build trust through partnerships among individual scientists, managers, regulators, and operators, instead of with groups/agencies who are associated with competing agendas or positions. Mistrust can be avoided when the core of collaboration is between scientists dedicated to understanding the issues and the systems being studied.*
- *Try involving environmental managers on the State level.*
- *Get early involvement of AFO/CAFO owners and operators on environmental or human-health issues that will require scientific investigation and possible regulation. Communicate that it is not the agenda or desire of government agencies, nor is it in the national interest, to put owners and operators out of business, but rather to help them operate in an environmentally friendly way.*
- *Develop incentive and reward programs for operators who implement practices to protect the environment; encourage collaborative efforts between AFO operators and scientific investigators; offset economic loss from conscientious efforts to implement environmentally friendly practices.*
- *Policies regulating agricultural industries should follow the same regulations for accountability as that dictated for other industries.*
- *The USGS should redouble efforts to achieve the state-of-the-art in microbiological sampling and to incorporate microbial data collection and analysis as routine components of water-quality studies.*
- *Disseminate the information presented at this conference to members of the industry as well as to other stakeholders.*
- *Work toward getting support from industry groups and advocates (such as the fast-food industry, Pork Producers Association, Cattlemen's Association, National Association of State Departments of Agriculture).*

5. Where do we go from here?

- **Follow-up workshop(s) and/or training**
    - *Continue to periodically hold meetings such as this one. Additional topics should include mortality, protein recovery, and rendering issues.*
    - *As part of a future workshop, hold a session on medical issues and how environmental studies can help in collecting the data needed to make assessments with regard to human health.*
    - *Develop primers, courses, and forums to help learn about and address subtopic issues, and enhance interdisciplinary exchange.*
    - *A USGS course on microbial source tracking would be very useful.*
    - *A forum is needed on tracer technology.*

- **AFOs e-mail list and web site –** Develop an e-mail list and/or maintain the current web site for updates on AFOs activities and to promote information sharing and dialog. Publish the proceedings from this meeting on the web site and provide links to data sources.
- **AFOs interest group –** An AFOs multidisciplinary interest group could be established, modeled after that of the USGS-sponsored Abandoned Mine Lands interest group. This could provide a foundation for trust building.
- **Analytical methods –** The USGS should keep an up-to-date web site that provides information about the analytical methods that are approved and that are being developed for emerging contaminants (such as pesticides, pesticide degradation products, antibiotics, hormones, mercury, arsenic, and selenium), the method detection limits, and who is developing the method or providing the analytical services. This should include USGS work being done by its National Research Program scientists; Water, Geology, Biology, and Mapping Division scientists; as well as that of its National Water Quality Laboratory.
- **Multidiscipline collaboration and outreach**
    - *Identify 2 to 3 geographic study locations that could be used as a point of focus and collaboration for a consortium of stakeholders, including government scientists. Possible locations with monitoring infrastructure and/or ongoing studies: Delmarva Peninsula paired watersheds; the Arkansas-Savoy watershed study area; Shoal Creek, Missouri, investigation; or a National Water-Quality Assessment (NAWQA) Program study site.*
    - *Use the U.S. Department of the Interior National Irrigation Water Quality Program as a model to set up a similar effort for CAFO/AFOs.*
    - *Begin efforts to jointly fund studies among agencies specializing in different and complementary areas of expertise.*
    - *Multi-agency collaboration is needed to identify problems associated with AFOs and the actions needed to address the problems; for example, work with the U.S. Food and Drug Administration to help prevent problems resulting from feed additives.*
    - *Implement the suggestions listed in question 4 (above).*
    - *Work for funds, legislation, and public awareness that will bring about a change in attitudes between public and private sectors. Focus on outreach education for local politicians and the public, showcasing specific areas of expertise (for example, hydrologic modeling).*
- **Science and technology**
    - *Develop contaminant remediation technologies and prevention strategies.*
    - *Develop a multi-agency plan to address the scientific questions and needs identified in question 1 (above).*
    - *Do not reinvent/re-research. Examine the literature and learn from investigations, research, and practices implemented in Asia and Europe. For example, there is a huge database and wealth of information from the 7th International Symposium on Animal, Agricultural, and Food Processing Waste (American Society of Agricultural Engineers).*

- **Policy**
  - *A mechanism, such as Superfund, should be considered by the regulatory agencies to address remediation of sites that already are heavily impacted.*

Author Index